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THE STRUCTURAL ENGINEER

THE JOURNAL OF THE
INSTITUTION OF STRUCTURAL ENGINEERS

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Technical Education and Professional Training
by D. A. G. Reid (Member of Council)

Modern Methods of Fabricating Structural Steelwork
by M. F. Palmer (Member) and R. J. Fowler (Member)

The Influence of Shear on the Moment of Resistance of Reinforced Concrete Beams
by K. Subbiah and R. B. L. Smith (Associate-Member)

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Main Contractors:
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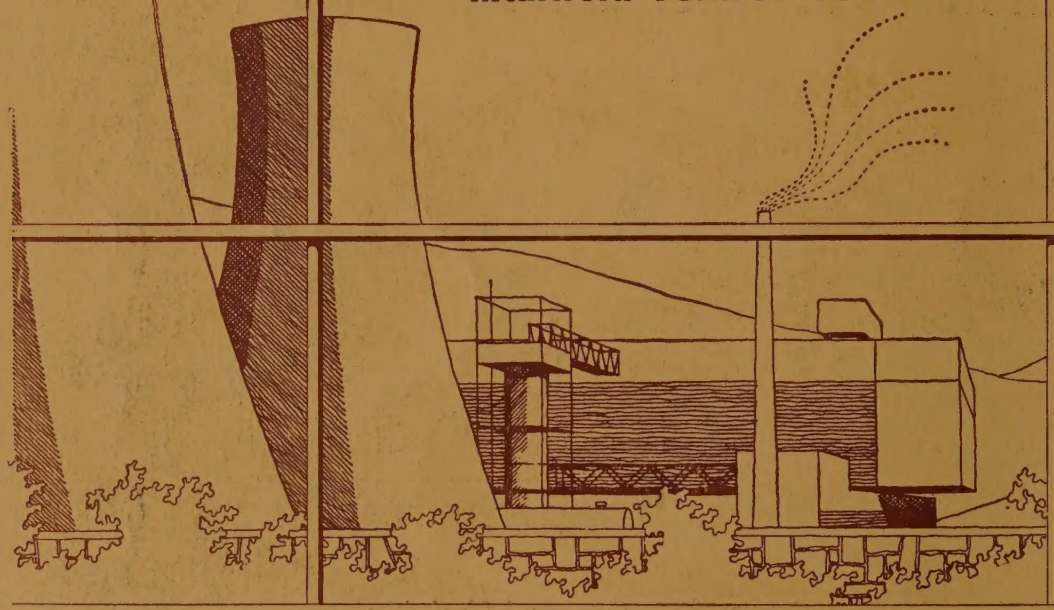

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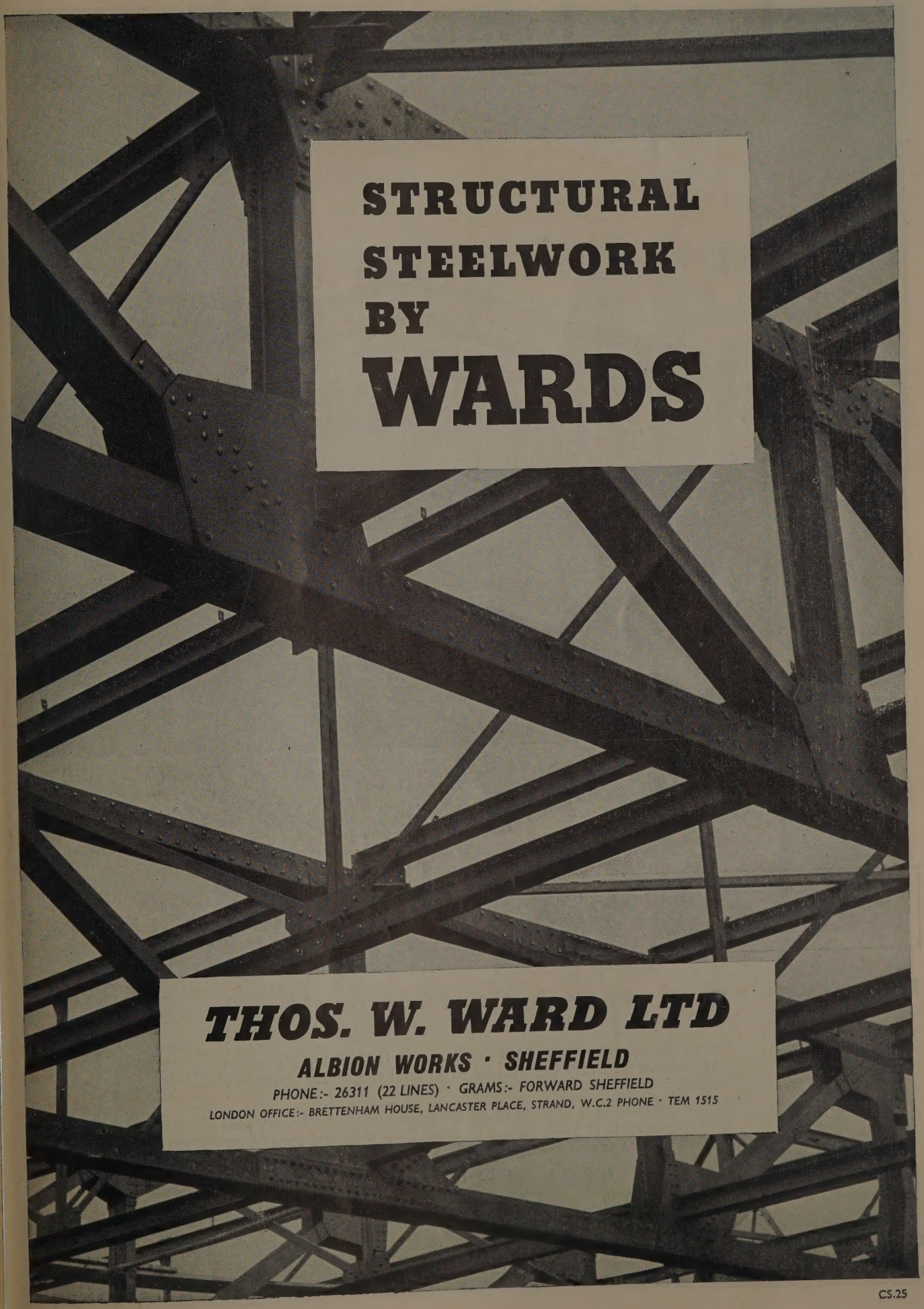
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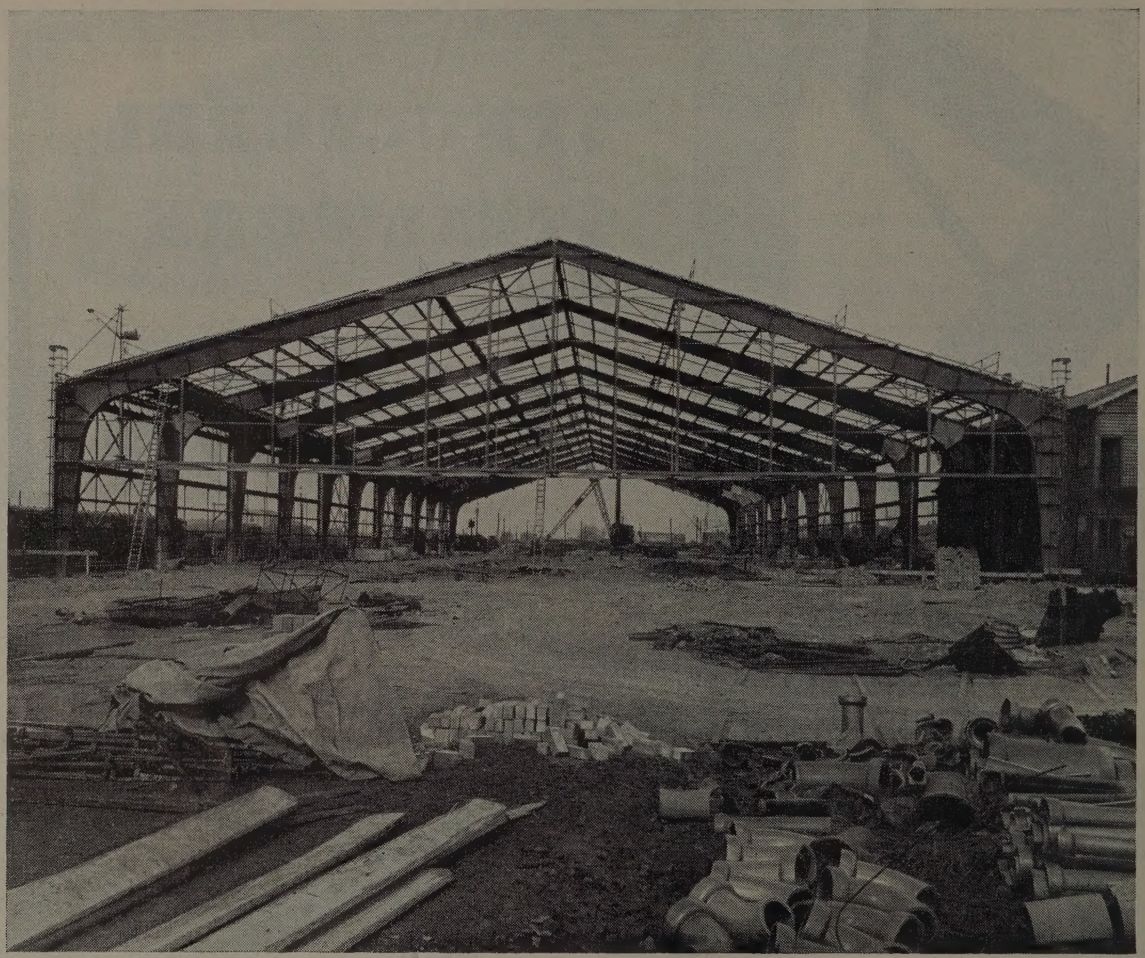

British Railways, Lincoln. Modernisation of Holmes Yard Goods Depot. Structural Steelwork for Perambulation Shed.

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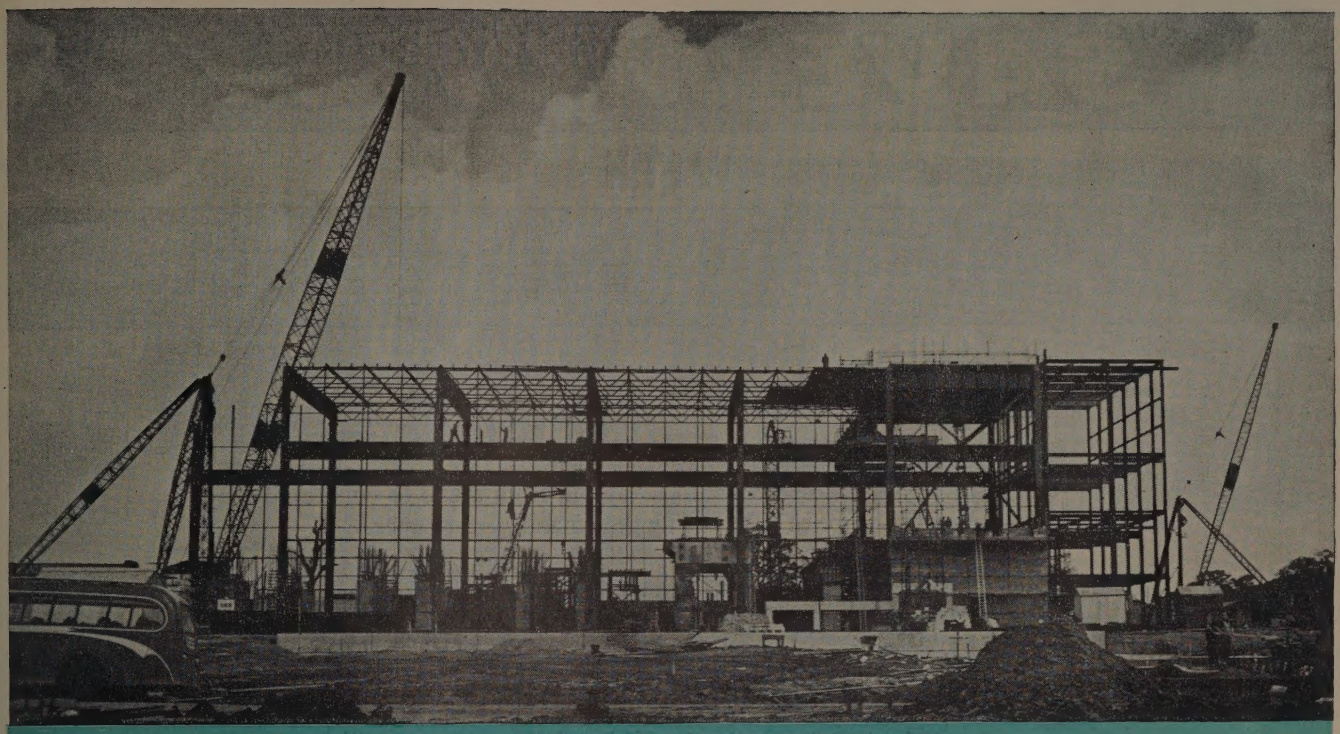

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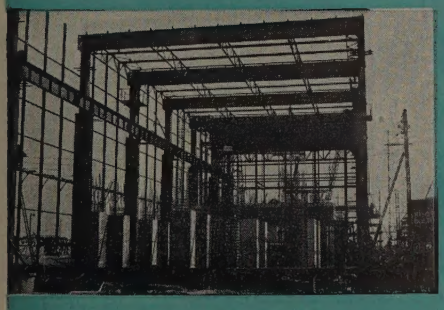

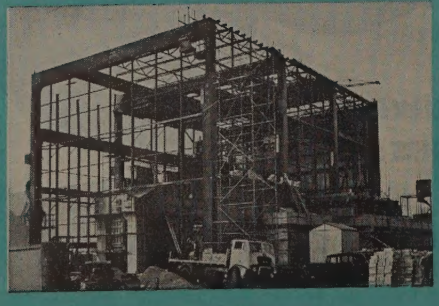

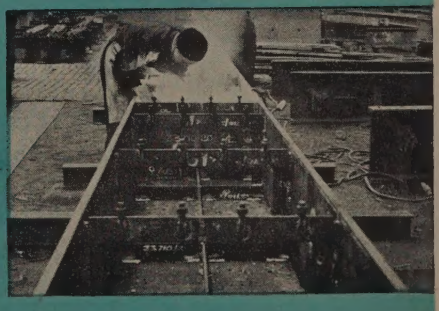

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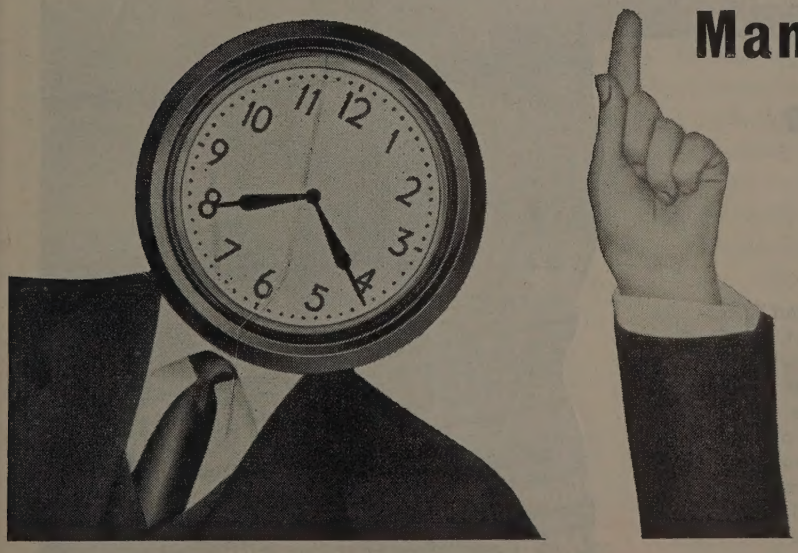

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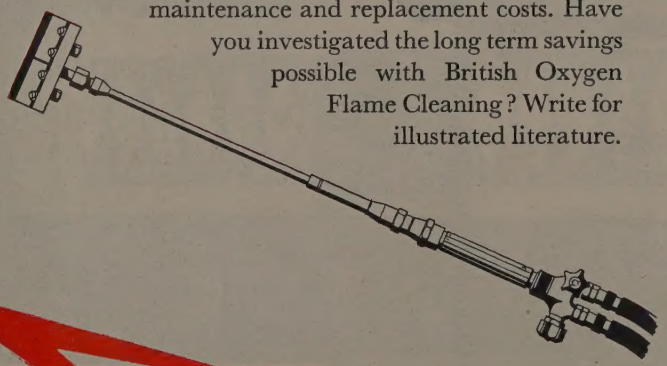

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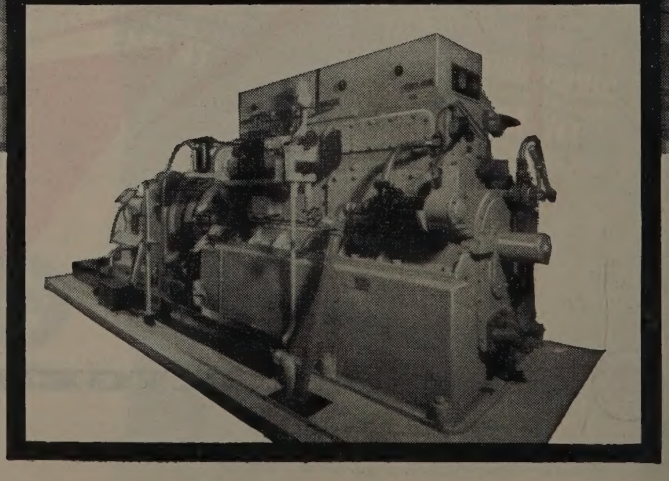

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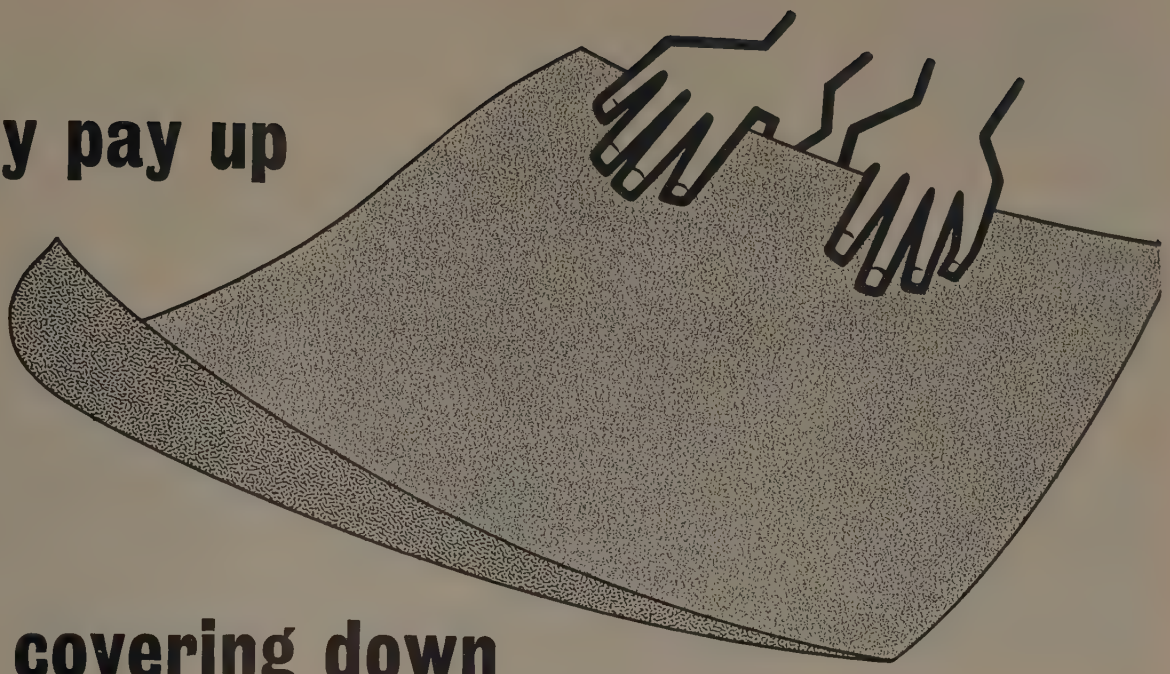

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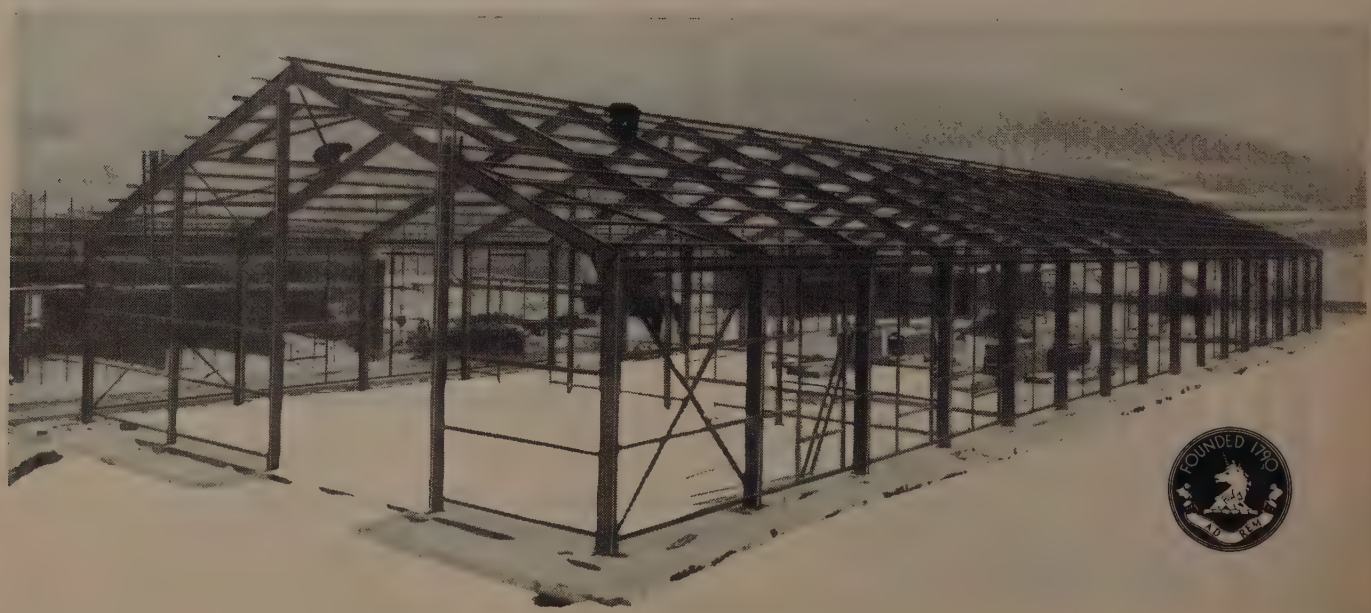

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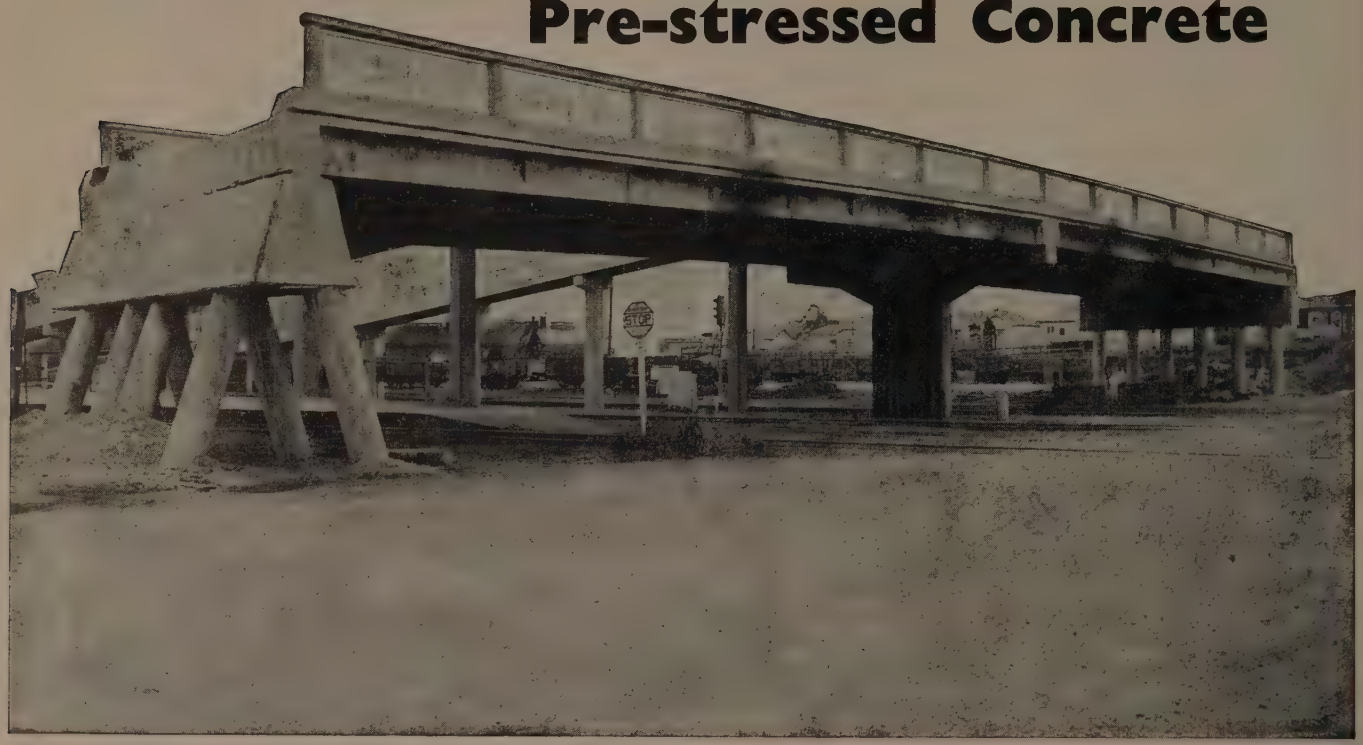

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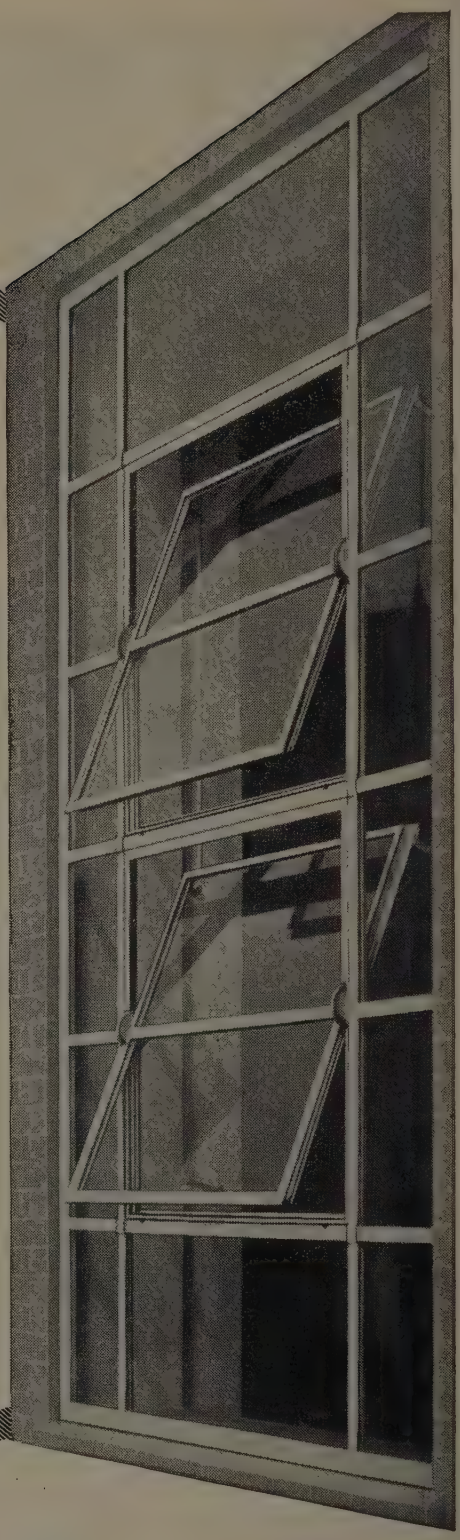

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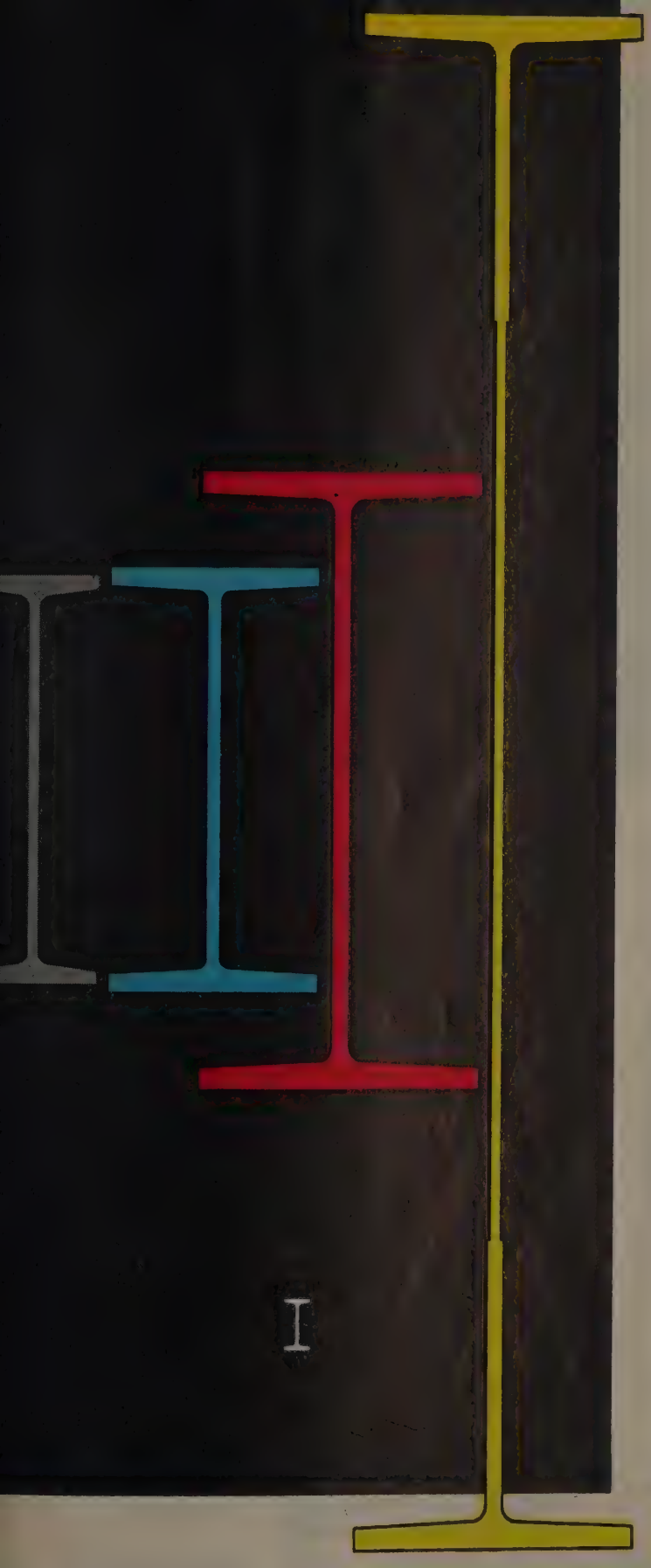

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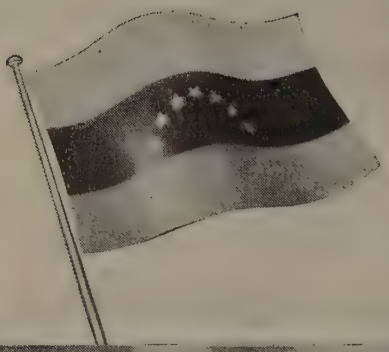

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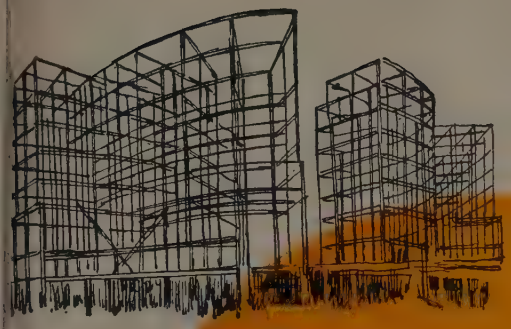

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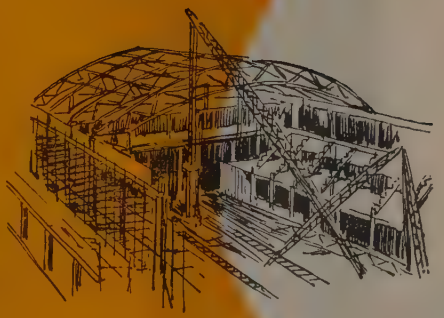

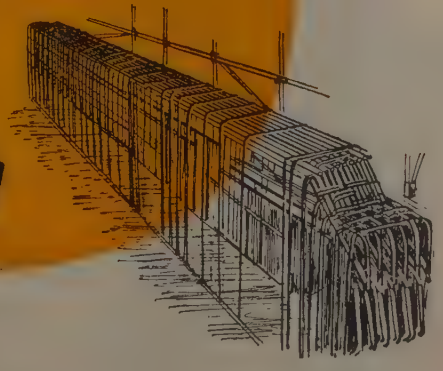

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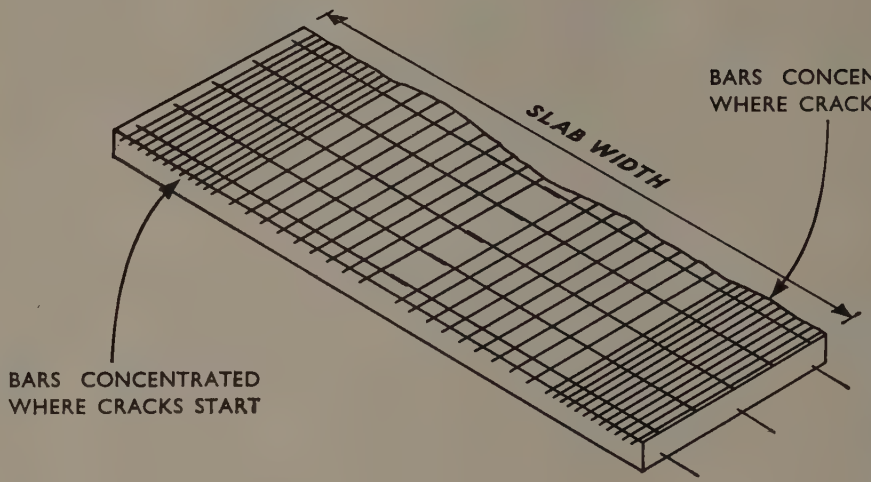

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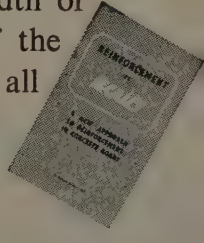

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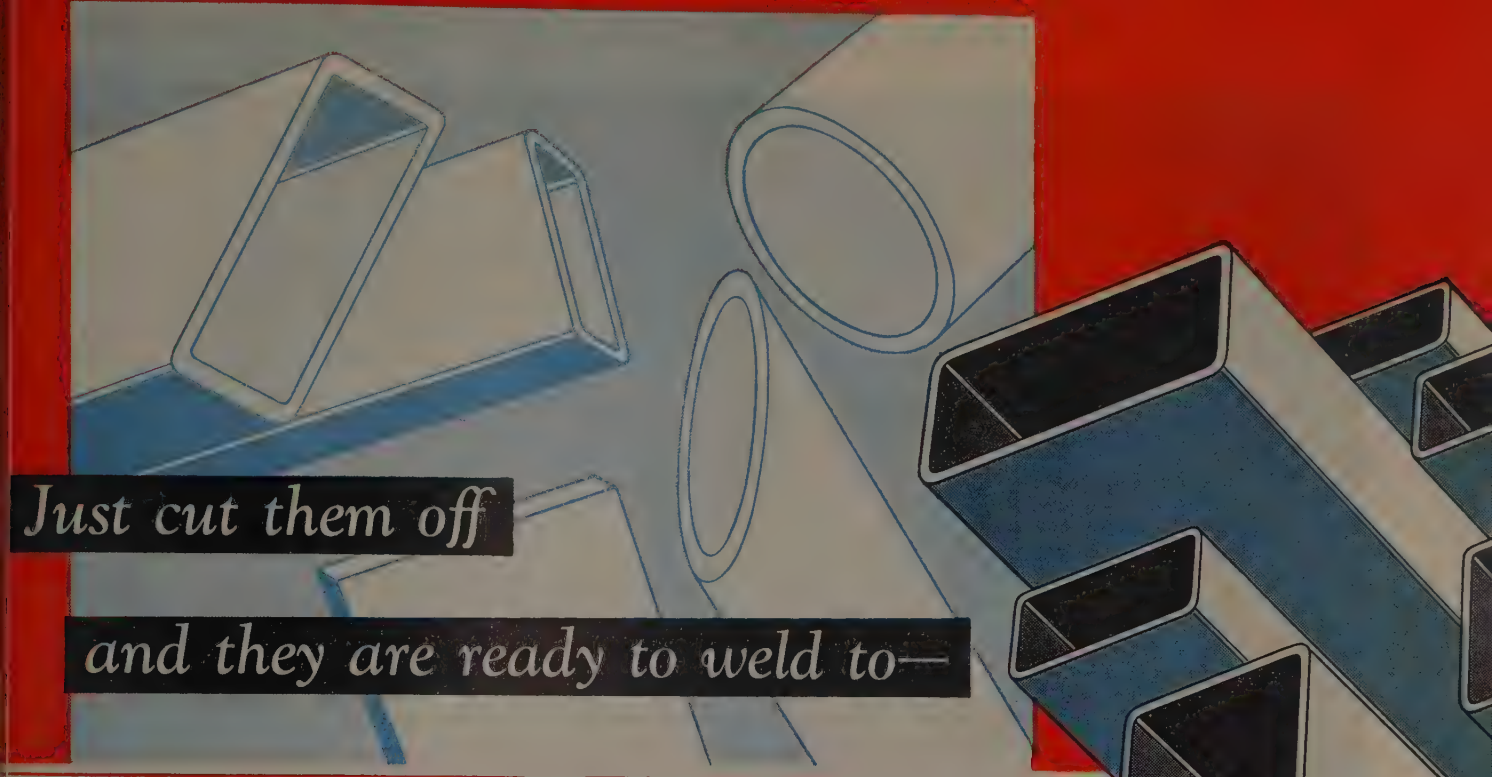

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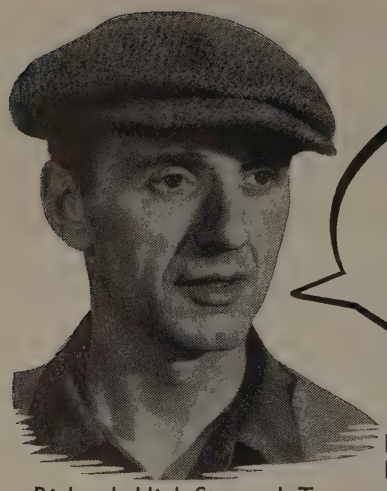

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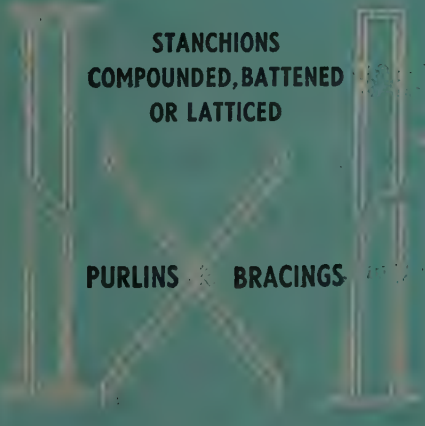

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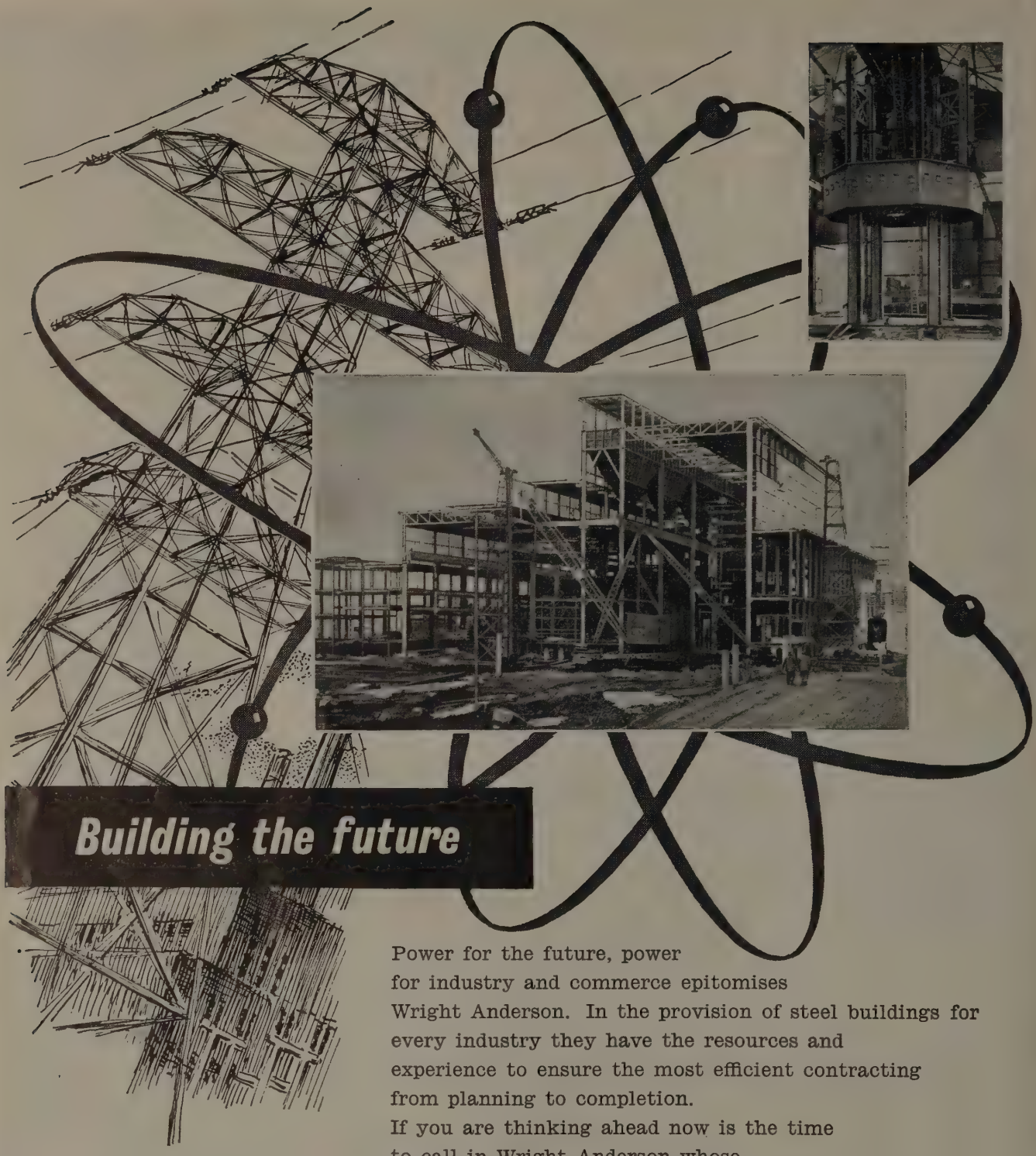

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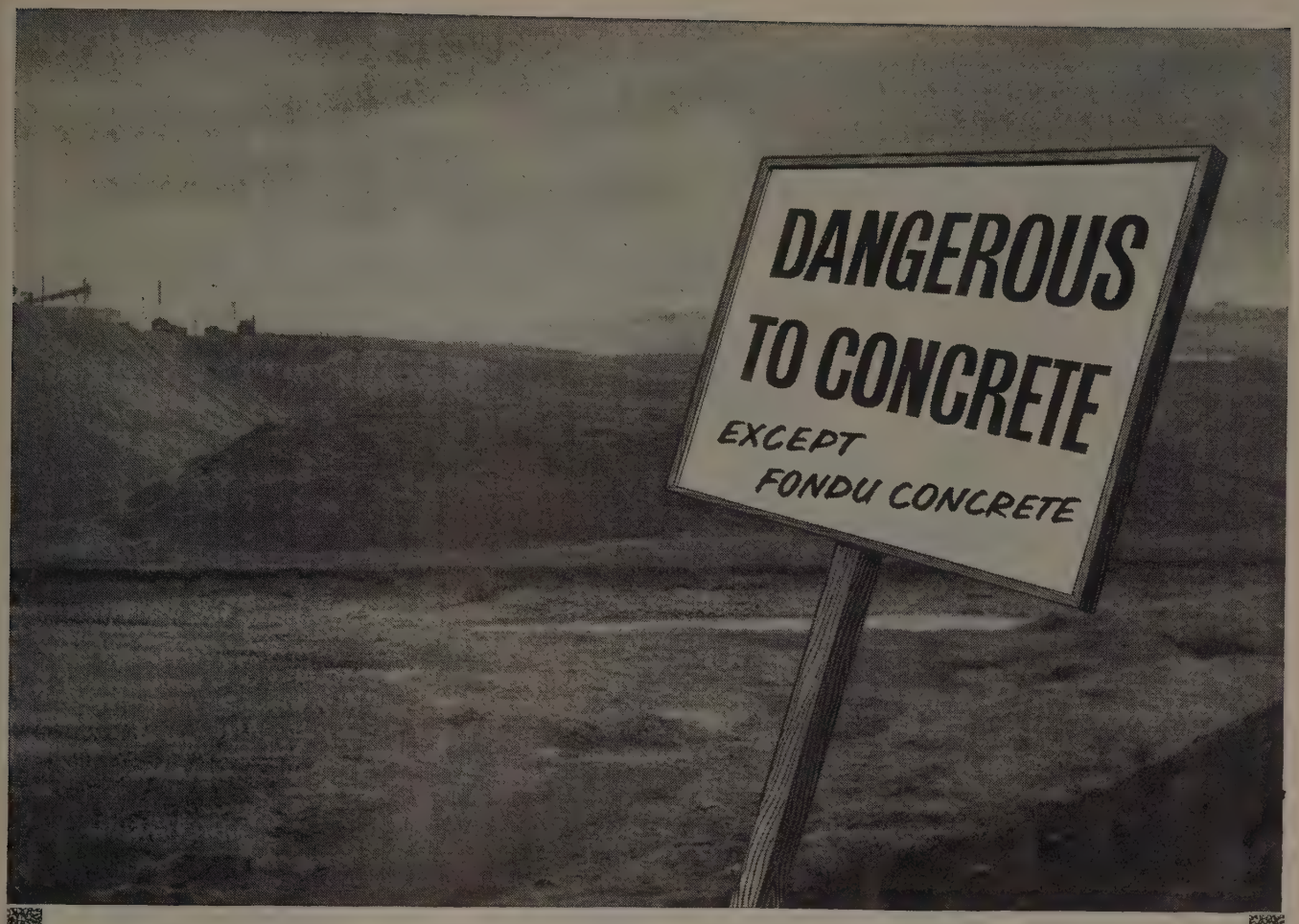

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CONTENTS

PAGE

TECHNICAL EDUCATION AND PROFESSIONAL TRAINING .. 357
By D. A. G. Reid, B.Sc.(Eng.), M.I.Struct.E., M.I.C.E. (Member of Council)
The Structural Engineer, November, 1958

MODERN METHODS OF FABRICATING STRUCTURAL STEELWORK 365
By M. F. Palmer, M.I.Struct.E., M.I.C.E., and
R. J. Fowler, B.Sc.(Eng.), M.I.Struct.E., A.M.I.C.E., A.M.I.Mech.E.
The Structural Engineer, November, 1958

THE INFLUENCE OF SHEAR ON THE MOMENT OF RESISTANCE OF REINFORCED CONCRETE BEAMS 377
By K. Subbiah, B.E.(Andhra), M.Sc.Tech. and
R. B. L. Smith, M.Sc.Tech., A.M.I.Struct.E.
The Structural Engineer, November, 1958

BOOK REVIEWS 364, 384

INSTITUTION NOTICES AND PROCEEDINGS 385

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Technical Education and Professional Training*

By D. A. G. Reid, B.Sc.(Eng.), M.I.Struct.E., M.I.C.E., (Member of Council)

Introduction

It is now over twenty-five years since the Institution discussed a paper dealing with technical education, the last occasion being in 1931 when my distinguished predecessor, Mr. F. E. Drury presented a paper on the subject. Mr. Drury included some further references to the education and training of structural engineers in his Presidential Address in 1945.

During the intervening period far-reaching changes have taken place in the attitude of industry and of the nation at large towards education in general and towards technical education in particular and these changes have, in turn, influenced the policy of professional institutions in respect of their requirements for admission to corporate membership. The Council and the Education and Examinations Committee of this Institution have had the examination structure under almost constant review for the last ten years and, a year ago, the Council approved proposals for a new scheme which will come into force in 1961. Other engineering institutions also have changes in prospect so that, although there is no slackening in the rate of development, a stage has been reached at which it is possible to discern the general outlines of the picture of technical education as it is likely to appear during the next ten years.

War-time Developments

THE build-up of the present climate of opinion in respect of technical education and training may conveniently be divided into two parts, that which took place during the 1939-45 war and that which has taken place subsequent to 1945.

The development during the war was a remarkable phenomenon only partly to be accounted for by the technical demands of the war effort. No official statistics are available for the years between 1938 and 1947 but there is good reason to believe that the great increase in day-release for technical studies which took place during those years commenced about 1942. (See Fig. 1). Fig. 2 shows that admission to corporate membership of engineering Institutions also increased more rapidly from about that time. There was a corresponding increase in the number of full-time students in attendance at technical colleges, some of which could be traced directly to the demands of the armed forces (e.g. Engineering Cadets Courses). For a substantial part of this increase, however, other reasons must be sought. Increased prosperity and a loosening of competition in industry undoubtedly played its part in encouraging day-release of young employees, particularly when some deferment of call-up might be granted to young men undergoing certain types of training. Furthermore, the extreme shortage of skilled labour engendered a fresh sense of the value of technical skill in all its forms and of the need to make provision for the proper training of young people. During 1941 the words " post-war reconstruction " may have been little more than a contribution to national morale devised to distract people's minds from the immediate

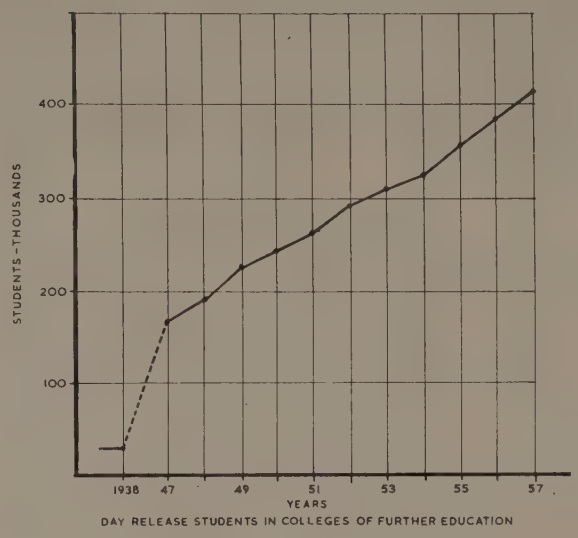


Fig. 1

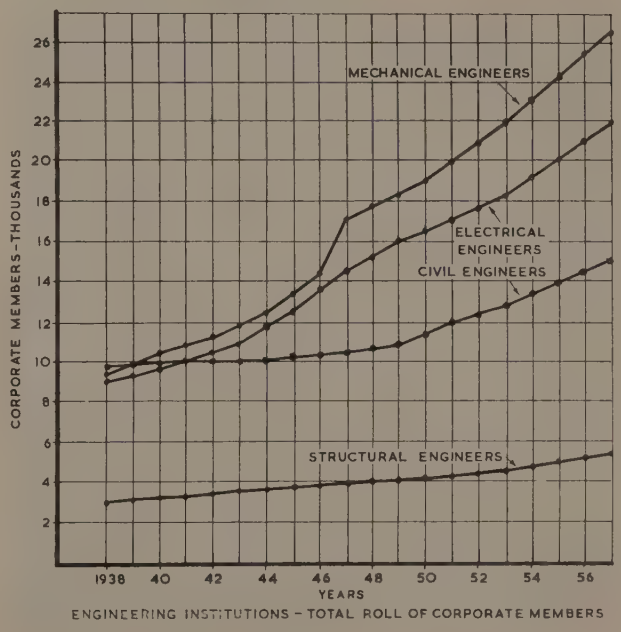


Fig. 2

hardships and perils but, as the war progressed, they became identified with an increasingly strong part of public opinion which sought an outlet from the economic stagnation of the nineteen-thirties. Those of us who had a special interest in building were stimulated by the move towards a National Scheme of Apprenticeship for the Building Industry which took shape during 1943 and, on a wider scale, the same movement brought about the Education Act of 1944.

Altogether, the technical colleges were in a far stronger position in 1945 than they had been in 1939. Whereas, before the war, the colleges needed Junior Technical Schools on their premises in order to maintain a nucleus of full-time staff, the post-war removal of those schools to their own premises was, in many cases, necessary to make room for the expansion of the

* *Paper to be read before the Institution of Structural Engineers, at 11, Upper Belgrave Street, London, S.W.1, on Thursday, 13th November, 1958, at 6 p.m.*

full-time and day-release work which had already commenced and was evidently likely to progress rapidly during the immediate post-war period. It was the Education Act of 1944 that changed the Junior Technical Schools to Secondary Technical Schools and separated them from the other branches of technical education. There were many who deplored this change at the time and some, indeed, today feel that the education system lost something which has never been replaced. As time goes on, however, and the new secondary school system develops, the wisdom of the change becomes increasingly apparent and the true functions of the technical colleges are more closely appreciated.

Post-War Developments

The period immediately following the end of the war saw an immense increase in the work of technical colleges. A great part of this increase came from the enrolment of full-time students who were given grants under the Government's Further Education and Training Scheme. A young person who could show that his (or her) training for a recognised professional qualification had been interrupted by call-up was eligible for a grant sufficient to cover fees and maintenance during a period of full-time study sufficient to allow him to pass the final qualifying examination. This far-sighted scheme had important results, some of a long-term nature and of wider significance than the immediate purpose of the Scheme itself.

There was, of course, a great influx of new corporate members to the professional institutions (see Fig. 2) and this had the effect of raising, still further, the prestige and strength of these institutions. For the next generation of students following the ex-service men, full professional status was regarded as the normal expectation of the competent student with an adequate background of general education and the number prepared to pursue their studies and training to the achievement of this objective was far greater than had been the case in pre-war days. Full employment and the expansion of industry contributed greatly to this development by offering both the opportunities for training (including day-release for part-time students on a steadily increasing scale (Fig. 1)) and a growing demand for the services of those holding professional qualifications. Apart from the expansion of industry and of the professional services associated with industry, the nature of the work itself had changed during the war and continued to change afterwards; technical developments demanded a larger proportion of well-qualified personnel and the increase in professionally qualified engineers, far from creating a surplus on the labour market, was still inadequate to meet the demand for this type of staff.

Reference has already been made to the sense of value of technical skill which developed from circumstances during the war. Post-war conditions intensified this development and industrial organisations, both large and small, became increasingly interested in training and in the technical studies appropriate to the training of various types of staff. Firms which hitherto had had only the vaguest impressions of the work of technical colleges found it necessary to inform themselves as to the nature of National Certificate and Diploma Courses and of their relation to other courses of study provided in educational establishments. It had long been the practice of the most progressive industrial organisations to appoint an Education and Training Officer to supervise the progress of apprentices and trainees. During the post-war period this practice became much more general, among small firms as well as large, to the point at which any organisation interested in the recruitment and training of junior staff found it necessary to have someone specially responsible for these aspects of staffing. The demand for juvenile labour of all types was intensified by the conditions of full employment coming at a time when the total sizes of the age-groups of school leavers were at their lowest and competition for the more able boys and girls resulted in firms offering more attractive schemes of training in which day-release for technical studies occupied a prominent place.

The increased interest of industry in recruitment and training of young people had the effect of focusing the interest of a much larger proportion of school children and their parents upon the possibilities of careers in industry and in the technical professions. The requirements of professional institutions in respect of general education encouraged continuance at a secondary school at least to the age of 16, when Ordinary Level examinations in the General Certificate of Education could be taken, and this contributed to the tendency of children to stay longer at school, a further restriction on the availability of school leavers. There was a corresponding increase in the number of pupils taking sixth-form courses at secondary schools and proceeding to university degree or college diploma courses. The engineering industry had well-established arrangements for the recruitment and training of university graduates and the increased output from the universities was readily absorbed.

Within the technical colleges the organisation of day courses, both full-time and part-time, created a great demand for additional full-time staff. Fortunately there was a considerable number of part-time teachers with valuable industrial experience who were prepared to make technical teaching their career and the colleges managed to achieve a rapid expansion of their teaching staffs though there was then, and has been ever since, great difficulty in recruitment of staff in certain fields of professional work, particularly where specially high academic qualities are desirable.

The development of day-release courses established relations between the technical colleges and industry of a different type from those that had hitherto existed. There had always been much goodwill between the two and, during the 1919 to 1939 period, the colleges had worked hard to foster good relations with industry, to inform industry of the nature of technical college courses and to engender an interest in day-release classes for apprentices and other trainees. The harvest of this twenty years of work was reaped after 1945 and its very richness created new problems for the colleges. It was necessary not only to organise courses and to find accommodation, teachers and equipment for large numbers of students; it was also necessary to devise means of supervising the attendance and progress of these students, some of whom lacked the ambition and persistence that had characterised their forerunners in evening courses. Day-release for attendance at technical colleges is, inevitably, less valued by individual students as a privilege when it becomes a normal part of schemes of training and the attitude of part-time day students in National Certificate and professional courses is much the same as that of secondary grammar and technical school pupils to their school work. The majority attend without question and work well if they are well taught; a minority do no more than they can avoid without trouble. Technical colleges recognised, very quickly, their responsibilities to employers for close supervision

of attendance and progress of students but usually found themselves short of administrative and clerical assistance in providing a full information service. The firms themselves appeared often to find difficulty in giving proper attention to such information as was supplied by the colleges and this was one of the reasons for the appointment of education and training officers who could maintain close contact with the colleges and exercise careful and individual supervision of the progress of trainees. In many cases, these officers had had experience of technical college teaching and, therefore, knew the colleges from the inside. They have played a valuable part in developing the new pattern of relations between industry and the colleges which has taken shape during the last ten years but which only recently has reached the point of tackling some of the more difficult problems of training for industry. Such problems include the defining of criteria for selecting students for courses, for governing advancement within courses and transfer between courses of different types. Industry has become increasingly conscious of the cost of training and of the wastage resulting from the failure of trainees to complete their training. The more careful supervision of recent years has made possible some measurement of this wastage, the indispensable first step towards its reduction. The reduction itself will demand another advance by industry in the training field, an advance with which the technical colleges will be closely associated.

Developments in the organisation of technical education have also occupied an important place among post-war activities in this field. Up to 1939, the difficulty of securing support from industry for any activities outside a simple programme of evening courses resulted in colleges growing more on account of the personalities of their principals and heads of departments than of the real needs of the industries of their region. Towards the end of this period there was recognition of the need to organise the activities of colleges jointly serving the needs of well-defined regions so that the relatively few students taking advanced courses could be collected at colleges where accommodation and equipment, staffing and geographical situation provided the best opportunities for the efficient operation of such courses. It will be appreciated that this type of direction must inevitably encounter opposition arising from sense of local prestige and the loss of advanced work laboriously built up by local effort. This very controversial matter was one of those considered by a select Committee set up in 1944 under the Chairmanship of Lord Eustace Percy (now Lord Percy of Newcastle). In their Report, published in 1945, the Committee recommended the establishment of Regional Advisory Councils to cover the whole area of England and Wales, each Council being responsible for the distribution of courses within its own area.

The recommendation of Lord Percy's Committee was accepted and ten Regional Advisory Councils were set up in 1947. The nature of their work differs somewhat as between different regions and, on account of difficulties of the type to which reference has already been made, all the Councils have had to proceed cautiously. They are now accepted as an integral part of the system of technical education and can fairly be said to have established their worth. In Scotland five Councils were established in 1949 though, in the more populous areas, regional organisation was well advanced considerably before that time.

Lord Percy's Committee also considered questions affecting the prestige of technical education. Until recent years, careers in industry and commerce have, in this country, commanded less respect than careers in the older professions and, accordingly, the highest achievements of the technical colleges did not receive the same public recognition and financial support as was accorded to the universities. The need for some action to adjust this situation was generally felt at the end of the war and the Percy Report contained two recommendations directed towards this end. It was suggested that a limited number of suitable colleges should be selected for development of advanced studies and research and that a new award should be established in connection with advanced studies in technical colleges, the courses leading to the award to be comparable to those leading to a university first degree. These recommendations aroused great controversy and several years elapsed before sufficient general agreement could be reached to permit of steps being taken towards their implementation. In 1955 a new independent body, The National Council for Technological Awards, was set up under the chairmanship of Lord Hives and, in the following year, the Council published a Memorandum setting out the conditions for recognition of courses leading to its first award, the Diploma in Technology. Rapid progress has been made during the past two years in the establishment of these courses to which further reference will be made in the next section of this paper. In 1956 the Minister of Education designated eight major technical colleges as Colleges of Advanced Technology and directed that these colleges should divest themselves of all work other than that connected with advanced studies and research. A ninth college has since been added to this list. In a Circular, also issued in 1956, the Minister gave details of the Government's intentions in respect of the future structure of technical education. Besides the Colleges of Advanced Technology, already mentioned, this was to consist of a limited number of Regional Colleges, in which advanced studies (including Dip. Tech. courses) would occupy a prominent place, a larger number of Area Colleges and a larger number still of Local Colleges in which the bulk of elementary work would be carried out. It was emphasised that it was not the intention to create a static pattern of colleges and that development of the work of colleges would still be encouraged to meet the needs of industry and commerce and that, consequent upon such development, certain Local Colleges might come to assume responsibilities to a larger area, Area Colleges to a larger region and so on. The setting-up of this framework of colleges has made possible a firmer policy for the concentration of existing courses and the development of new ones and has strengthened the hands of the Regional Advisory Councils. It is, as yet, too soon to observe the full effects of the new conditions but it is clear that the old personal, almost anarchic, development of technical college work has gone with the industrial indifference to education and training which created it.

Post War Changes in Curricula and Syllabuses

The development of National Certificate schemes was the principal achievement of technical education during the inter-war years and was made possible largely by the recognition which engineering Institutions were prepared to accord to the Certificates. The normal pattern was a three-year course leading to the Ordinary National Certificate followed by a further two-year course leading to the Higher National Certificate. Students who had continued full-time education to the age of 16 and reached certain standards in appropriate subjects might be exempted from

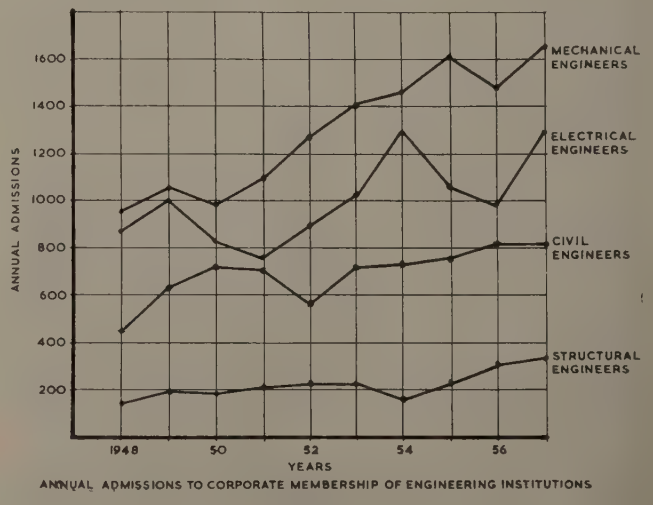
part or the whole of the first year of the Ordinary course. Arrangements could be made for additional subjects to be studied after the completion of the Higher National Certificate course and, subject to passing an examination, for these subjects to be endorsed on the Higher National Certificate. Holders of a Higher National Certificate in Mechanical Engineering with appropriate endorsements were exempted from the whole of the examinations leading to Associate-Membership of the Institution. The Institution of Electrical Engineers gave complete exemption from their examinations to holders of a Higher National Certificate in Electrical Engineering without endorsements but, after 1933, the examination marks in two electrical engineering subjects both at the Ordinary and at the Higher National Certificate stage were required to reach a " Credit " level of 50% instead of the normal pass level of 40%. The Institution of Structural Engineers gave more limited recognition to Higher National Certificates in Engineering or Building provided Structural Engineering subjects formed part of the course. No National Certificate scheme in Civil Engineering was established until 1943 and, when Rules for such schemes appeared in that year, they contained certain unusual features. In the first place, no separate Ordinary National Certificate courses were contemplated; entry to a Higher National Certificate course in Civil Engineering could be obtained through an Ordinary National Certificate in Engineering or, alternatively, through an Ordinary National Certificate in Building provided the studies of mathematics and science in the course were taken to an appropriate level. Secondly, the Higher National Certificate course itself extended over three years and exemptions in respect of the Institution of Civil Engineers Associate Membership Examination were given on a subject-for-subject basis.

National Certificate courses in general included three subjects in each year of the course, reflecting the attendance requirement of three evenings per week normally expected for any part-time grouped course at the time when the first National Certificate schemes were established. In the three years of the Higher National Certificate course in Civil Engineering it was possible to cover all the subjects in Section B (later called Part II) of the Institution Examination and also, in conjunction with the work done in the Ordinary National Certificate course, to cover the requirements of two of the five subjects included in Section A (later called Part I) of the Examination, these subjects being Applied Mechanics and Theory of Structures. The three remaining subjects in Section A were: (a) English, for which exemption could be claimed for a pass in the School Certificate Examination (later, the Ordinary Level examination in the General Certificate of Education), (b) Heat, Light and Sound, and (c) Principles of Electricity. The position then was that a student could no longer expect to cover the Institution requirements in six years of evening study through a National Certificate course, at least one additional year being required to make up the Section A subjects. This additional year was usually taken after the completion of the Higher National Certificate course when the subjects in question could be endorsed on the Higher National Certificate. After 1945, the Institutions of Mechanical and Electrical Engineers also introduced additional endorsement requirements in respect of these basic subjects, so extending by a year the length of part-time courses necessary to secure full exemption from the irexaminations. In the latest revision of their schemes, these Institutions require this particular endorsement to be obtained on the Ordinary National Certificate so that the study of basic subjects is completed before the Higher National Certificate course is commenced, educationally an eminently sound arrangement.

The Institution of Structural Engineers introduced a new scheme of examinations in 1945 with a Graduateship and an Associate-Membership Examination of which it is not necessary to give full details here. Full exemption from the Graduateship Examination was accorded to holders of Higher National Certificates in Engineering or Building on the same terms as previously but no exemptions from subjects in the Associate-Membership Examination were obtainable through part-time courses except in respect of a first class Full Technological Certificate of the City and Guilds of London Institute in Structural Engineering. Nevertheless, adequate preparation for the Associate-Membership Examination could be provided by one year's additional study beyond the Higher National Certificate stage provided the subjects of the Higher National Certificate course itself were suitably chosen. In 1949 arrangements were made for the President of this Institution to countersign Higher National Certificates in Civil Engineering when the course had had a strong structural bias, and this applied to the large majority of the Civil Engineering Certificates awarded. The countersigned Certificates were accepted by this Institution as exempting candidates from the subject Theory of Structures in the Associate-Membership Examination. Similar recognition was later accorded to other Higher National Certificates in Engineering or Building with appropriate endorsements in respect of an additional year's study of structural engineering subjects subject to approval of the syllabuses in each individual case.

In the field of full-time courses, it was a long-established practice for the engineering Institutions to accept the degrees of British (and some overseas) universities in the respective branches of engineering as providing complete exemption from the examinations for admission to corporate membership. Such candidates had still, usually, to satisfy some special requirement of the Institution which might take the form of a professional interview, the presentation of a thesis or, in the case of this Institution, the passing of an examination in two subjects: (a) Structural Design and Drawing, and (b) Specifications, Quantities and Estimates.

Table 1 shows the distribution of new Associate Members admitted to four engineering Institutions in



ANNUAL ADMISSIONS TO CORPORATE MEMBERSHIP OF ENGINEERING INSTITUTIONS

Fig. 3

1957 as between university graduates, holders of Higher National Certificates or Diplomas and others. Although the number of annual admissions to corporate membership has risen considerably during the last ten years (Fig. 3), the proportions of entrants coming from the three categories of Table 1 have shown little variation.

Table 1

Distribution of Admissions to Corporate Membership. 1957.

Institution	Percentage of Admissions in each Category		
	Engineering graduates	Holders of H.N.C. or H.N.D.	Others
Civil Engineers	75	9	16
Electrical Engineers	49*	35	16
Mechanical Engineers	20	70	10
Structural Engineers	22	37	41

* Includes recognised Diplomas, probably 7%.

In the technical colleges there had, prior to 1939, been some development of three-year full time courses leading to the award of the Ordinary National Diploma after two years and the Higher National Diploma a year later. Higher National Diplomas usually received recognition from professional institutions comparable to that given to Higher National Certificates. After 1945, the three-year course for the Higher National Diploma was separated from the two-year course for the Ordinary National Diploma, the conditions of admission to the Higher National Diploma course requiring two subjects at Advanced Level in the General Certificate of Education or an Ordinary National Certificate or an Ordinary National Diploma. In spite of greatly increased numbers of full-time students (Fig. 4), however, this scheme made only limited progress, many of the major technical colleges preferring to develop courses leading to the award of a college diploma. These courses were usually planned in consultation with a professional institution which, subject to approval of the curriculum and syllabuses, was prepared to give appropriate recognition to the course in respect of its examinations. In such cases, it was the normal practice for the college or the Institution to appoint an external examiner or assessor to safeguard the standards of work in the course. The first college diploma recognised by the Institution of Structural Engineers was that of Brighton Technical College which, in 1946, was accepted on the same terms as a university degree. Other colleges followed soon afterwards with courses covering fully the requirements of the Graduateship Examination and, after some years of operation, some of these were extended a further year and recognised, also, as qualifying for exemption from the subject Theory of Structures in the Associate-Membership Examination.

The advent of the award of Diplomas in Technology provided a great stimulus to the development of full-time courses at the highest level in selected colleges and courses in Mechanical Engineering, Electrical Engineering and Production Engineering comprised the large majority of the courses recognised by the National Council for Technological Awards during the first two years of the scheme. Civil Engineering courses were much less prominent among submissions from colleges and no specifically Structural Engineering course had been approved at the time this paper was written (Sept. 1958). The National Council attached great importance to the close association of college studies with training in industry and the majority of recognised courses were of the " sandwich " type in which periods of college study alternate with periods of industrial training over a course of about four years, the periods, both in college and in industry, usually extending over about six months each. A further reference will be made to this development in the next section of this paper. The conditions of admission to Dip. Tech. courses were, normally, either two subjects (Mathematics and an appropriate science subject) at Advanced Level in G.C.E. or a good Ordinary National Certificate. The value of an Ordinary National Certificate for this purpose was usually judged mainly by the marks obtained in the assessed examinations in the final year of the course ; colleges were encouraged to put forward their own proposals as to what should be accepted and, normally, the requirement was set at a minimum of about 60 per cent.

A requirement of Dip. Tech. courses to which the National Council attached great importance was that the courses should include " liberal studies." It was recognised that this was a new field of development and colleges were encouraged to experiment along their own lines in introducing subjects intended to broaden the student's educational background for a career in technology. It is, as yet, too soon to discern any general pattern in the treatment of this section of the courses but the most usual approach appears to be through studies of social history and industrial development, the treatment being such as to demand a good deal of reading and writing on the part of the student. One further important feature of Dip. Tech. courses has been the inclusion, in the final period, of a large " project," selected individually by each student, to which the allocation of time is usually expected to amount to at least six hours per week for two terms. Close association with research and development interests in industry could, it is believed, make this part of the course a stimulating experience for the student besides testing his initiative and his capacity for individual work.

During recent years, the engineering Institutions have tended to increase the scope of their qualifying examinations and to raise the standard of National Certificates accepted for exemption purposes. In 1952, the Institution of Mechanical Engineers raised the number of subjects in Part II of their Associate Membership Examination from three to four and, in 1953, the Institution of Electrical Engineers published a revised examination structure in which, in place of two papers in the former Section B, there were four papers in Part II and a further advanced electrical engineering paper in Part III. These changes had the effect, for part-time students, of increasing the extent of the studies still to be undertaken after the end of the Higher National Certificate course. The increased Part I requirements, to which reference has already been made, had made it very difficult for the evening student to complete his course in six years; the additional Part II and Part III work increased the length of the course to at least seven years. For students who had the benefit of day-release throughout their course, the time could in some cases be shortened by adding one evening class to each year of the course. Reference has already been made to the requirements of the Institution of Electrical Engineers in respect of " credit " standards ; the Institution of Mechanical Engineers have announced their intention of introducing a similar requirement in 1960.

The new scheme of examinations approved by the Council of the Institution of Structural Engineers is considerably more extensive than the old; separate examinations in mathematics, in geology and in materials are introduced and the syllabuses in theory and design of structures are extended. Arrangements for the recognition of exempting qualifications have still to be worked out but it seems almost inevitable that part-time courses will have to be lengthened in order to cover the work.

In this connection, it is interesting to compare requirements in the engineering field with those in architecture and in quantity surveying. The Royal Institute of British Architects has, for over thirty years, strongly encouraged full-time studies in schools of architecture for those seeking to qualify as architects. There has been little attempt to smooth the way for the part-time student either by granting day release or by reducing the extent of the testimonies of study he must produce. Few evening students have completed the course in less than seven years even after starting with the necessary background of general education in terms of School Certificate or G.C.E. Ordinary Level subjects. The evening course in Quantity Surveying, for students preparing for the examinations of the Royal Institution of Chartered Surveyors, has usually been planned over six years though it has been difficult to cover the curriculum satisfactorily by attendance on three evenings per week. The large majority of successful students have taken seven years or longer to pass the Final Examination. Only a small proportion of the students entering part-time courses in architecture or quantity surveying ultimately pass the Final Examinations of R.I.B.A. or R.I.C.S.

Professional Training

We have been very slow, in this country, to adopt methods of training other than through the normal routine work of a junior assistant in a workshop or office. Although an employer was expected to accept certain teaching responsibilities in respect of apprentices and articled pupils, these junior employees learned the practices of the trade or profession by assisting older employees in their day-to-day work. During the last 150 years, it has become increasingly difficult to depend upon employers taking their teaching obligations seriously and being prepared to allow training considerations to interfere with production. During the early part of this century the engineering graduate established his position both in industry and in professional practice by the rapidity with which he responded to training and by the quality of his subsequent work. He brought a fresh approach to problems of development and the exploitation of new ideas and has played a great part in boosting the acceleration of technological advance. It was the growing realisation of the importance of the engineering graduate's services to industry that brought the first signs of a new approach to training for industry. While holding firmly to the belief that an engineering graduate had much to learn on entering industry, far-seeing industrialists were prepared to experiment with training systems designed both to take advantage of the graduate's ability to learn quickly and also to give him a broad experience of the industrial activities of the training organisation. The results of this policy were such as to encourage its steady expansion and development during the inter-war years. The universities for their part became increasingly satisfied that the gaining of industrial experience was an aspect of training that could safely be left to industry and that their function was to provide a course of study, an intellectual discipline, which developed a young man's mind in such a way as to enable him to profit most from his industrial training and to achieve, subsequently, a rapid advancement. The engineering Institutions, as has been said, waived their examination requirements in respect of graduates while continuing to insist upon a certain period of practical experience for candidates for admission to corporate membership. The period for graduates was, however, fixed at the modest level of about three years and this, in course of time, was, in many cases, reduced to two years. At Glasgow and Sunderland there were early experiments with sandwich courses designed to promote a closer association of university studies with industrial training.

Professional consultants found difficulties in introducing these new training systems into their smaller organisations. The financial resources of a consulting firm are of a different order from those of an industrial organisation and the training costs were not so readily faced. It became increasingly common, therefore, for engineering graduates to be trained in industry and to gain extensive knowledge of industrial practice before taking up consulting work if their interests led them in that direction. The immense growth, during recent years, of the larger consulting practices has, to some extent, modified this trend.

Developments in the training of architects during the last 50 years have provided valuable evidence of difficulties associated with a different approach to professional training. Even before 1914, many architects felt that only a small minority of practices provided suitable opportunities for the training of architects and that a more satisfactory arrangement would be for the pupil to spend the whole five-year training period in a school of architecture where, besides pursuing an organised course of study of the basic principles of architecture, he could gain experience of a range of work far wider in scope than any but the largest offices could offer. The satisfactory completion of a course (including the passing of appropriate examinations) in a school of architecture recognised by the Royal Institute of British Architects was accepted as a qualification for admission to corporate membership of that body. In practice, over the last 30 years, the results of this system are an interesting mixture of success and failure. It has produced a large number of lively and imaginative architects and as liberal an education as is to be found in any of our educational institutions. On the other hand, the divorce from practice (even though many of the teachers were practising architects) robbed ambitious schemes of their reality and left the young architects in many ways ill-equipped to cope with the day-to-day work of professional practice. In 1951, the Royal Institute introduced a requirement of one year's experience in an architect's office for all candidates for admission to corporate membership and, in 1962, this requirement is to be increased to two years.

Some schools of architecture have experimented with "live" projects in which pupils of the school have collaborated with practising architects in the design and in the supervision of construction of buildings. A strong feeling has developed among architects that more radical changes are necessary if a satisfactory training system is to be evolved. The problem is complicated by the separation of the architectural profession from the industry responsible for the actual production of buildings, a separation which has

contributed much to the shortcomings of both profession and industry. The building industry seems now to be in process of fashioning a professional training system of its own and to be using engineering industry practice as a model. Whatever the future of architectural training, its immediate past suggests that there are some things that can be done in educational institutions and some things that must be done in practice and that the essence of training lies not only in the excellence of the parts but also in their efficient combination.

The importance of integrating college studies and industrial training was strongly emphasised by the National Council for Technological Awards in its Memorandum on the Recognition of Courses leading to the Diploma in Technology (1956). The conditions for the award of the Diploma require that the student shall spend at least one year in industry prior to receiving the award.

In considering courses submitted by colleges, the Council has paid very careful attention to those parts of the proposals relating to arrangements between college and industry for ensuring that proper use is made of the period spent in industry. In the first place, it is insisted that the same care must be given to the design of the industrial training programme as is given to the design of the course of study. Secondly, the college is expected to accept the responsibility of maintaining contact with the students during their periods in industry and of keeping a finger on the pulse of each student's progress. The fruits of this policy have yet to be seen but its effect upon the relations between the colleges and industry have been wholly to the good of both and it is certain that the lessons of experience of these training developments will be quickly learned. It is the close association with industrial training which will, from the outset, give to the Diploma in Technology a value of its own and its holders should be well-equipped to establish, for the award, its claim to be of a standing equal to that of an honours degree.

In view of what has been said in the previous paragraph in regard to integrating college study and industrial training, it is not surprising that many of the colleges submitting Dip. Tech. schemes have adopted a sandwich course arrangement consisting of alternate periods of six months each in college and in industry over a period of four years. This type of arrangement has been steadily gaining in popularity during recent years in spite of objections voiced from the educational and from the industrial or professional sides. On the one hand it is suggested that the interruptions to study occasioned by the periods in industry must lower the academic level of the course besides aggravating the difficulties of providing satisfactory service conditions for teaching staff. On the other hand, industrialists and professional men complain of the disruption of their organisations occasioned by trainees who are with them only for six months of the year. It is difficult, at present, to assess the true weight and validity of these objections. Sandwich courses are enjoying an immense vogue which may be followed by something of a reaction but, in the long run, their future depends upon the success of those passing through them. It may be that a long period of continuous study elicits the best response from certain types of students, but it is doubtful if such types include the most valuable future technologists. From the staffing point of view, the arrangement has advantages which may well balance the disadvantages. On the practical training side, there has been a good deal of objection expressed by civil engineers on account of the peripatetic nature of their work. This does, undoubtedly, add to the difficulties of organising training programmes though it is interesting to note that builders interested in training at this level are inclined to favour sandwich courses because they can be phased to match seasonal fluctuations in building activities. It may be that much of the opposition expressed by civil engineers is due to the understandable difficulties of consultants in organising practical training along lines adopted by large industrial organisations. Sandwich courses enable students to gain their first experience of industry considerably earlier than do full-time courses and this undoubtedly eases the transition from college to industry. This advantage alone justifies the large experiment with sandwich courses which is now taking place.

The Future

While it is possible to foresee the likely developments in engineering courses during the next ten years, the effects of the raising of standards during the last ten years have not yet been felt to any considerable extent. Not only have the ranges of subjects and contents of syllabuses been extended; the nature and scope of the questions set in examinations now call for a depth of study more appropriate to full-time than to part-time courses. The effect of this policy must be to widen the gap between the Higher National Certificate and professional qualification. Until recently this gap has been narrow and comparatively few keen students have been unable to cross it but it seems probable that, in the near future, there will be a rapid increase in the number of holders of a Higher National Certificate or comparable qualification who are not able to proceed to full professional status. The existence of sub-professional groups of this type is not new; they are to be seen in other professional fields, but the circumstances in engineering are likely to create special problems for the engineering Institutions. As things are in this country, these men are likely to feel the need of organisations to provide for their technical interests and the established engineering Institutions may have to decide whether or not to try and meet this need by the creation of new grades of membership.

There is no sign yet of a slackening of the growth of the four engineering Institutions of which particulars are given in Fig. 3. The annual admissions to corporate

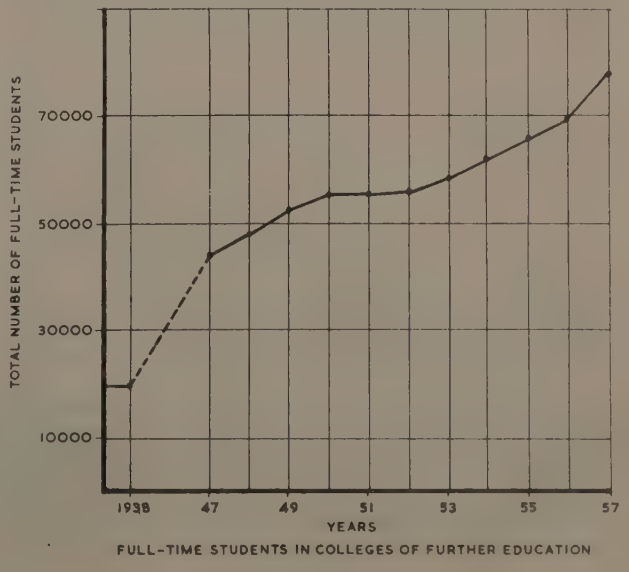


Fig. 4

membership are, in each case, still increasing in spite of the great expansion which has taken place during recent years. The influences to which reference has been made in the previous paragraph will tend to restrict this growth though the demand for technologists and the publicising of engineering as a career may well do more than compensate for the restriction.

From the point of view of colleges providing courses of study, the problem is not simply one of providing a course from which students drop out at different points. Students of differing abilities and potentialities (in terms of qualification) should be grouped in different courses; this already obtains in the field of full-time courses where there are three or four different types of engineering course available. In the field of part-time courses, the organisation is less advanced although the range of ability of student is much wider. With the greatly increased numbers of students and the closer control made possible by day-release and by supervision by training officers, the next few years should see the introduction of new types of course, less ambitious than the Higher National Certificate course but leading to a qualification more suitable than the Ordinary National Certificate as a final objective. The existence of alternative courses of this type might help considerably to reduce the wastage in National Certificate courses, particularly if industry and the professional institutions were prepared to take as great an interest in the development as they have in that of National Certificate courses.

I have made no attempt, in this paper, to deal with details of curricula and syllabuses of engineering courses but one aspect of them is worth a glance at this stage. The core of the academic discipline of an engineering course is mathematical and the real difficulties of a large majority of students in such courses are mathematical. There is some evidence to show that part-time students experience at least equal difficulties with basic science but it is doubtful whether this applies with any force, on present syllabuses, to those likely to reach a full professional qualification. It is open to doubt whether the chances of a man's qualifying as an engineer should, to so great an extent, depend upon his capabilities as a mathematician and current developments in engineering practice are tending to increase this doubt. Educational and professional institutions alike seem unwilling to experiment with the fundamentals of engineering courses though the nature of abilities required in engineering practice grows constantly more diverse. This is a problem which engineering Institutions must study very carefully if they are to continue to attract to membership a large proportion of those occupying the most important positions in the engineering world.

The urgent need to expand our national resources of technically trained men at all levels has been repeatedly emphasised during recent years. Targets have been set for rates of increase in the numbers of trainees at various levels and money is being made available for a corresponding increase in the facilities for technical study. The governing factor in this advance is the provision, by industry, of the necessary training places. Certain large organisations in the engineering industry have already made substantial contributions and the record in this respect of the manufacturing side of the industry compares well with that of other industries. On the civil and structural engineering side, much remains to be achieved and the most critical question of the immediate future is as to whether training facilities will be increased on the necessary scale. The construction industry faces international competition on a greater scale than ever before; its performance, measured by the cost of building, under the protected conditions of this country is more than ever important to the national economy.

The future of the industry and of its associated professions depends upon the training policies adopted now and it is vital that there should be a substantial increase in the resources devoted to training. The advances described in this paper apply to the best of current practice; the attitude of some employers towards training has changed little since 1939, and the average lags considerably behind the best. The time is critical; larger age-groups of adolescents are already leaving the secondary schools and the years from about 1960 until 1965 will offer the best opportunities for recruitment to professional training that have occurred for a very long time. The engineering Institutions are all striving to help recruitment but it is the individual members of the Institutions who will determine the success of the campaign.

Acknowledgments

I have received most valuable and willing co-operation in the preparation of this paper from the members of the staffs of the Institutions of Civil, Electrical, Mechanical and Structural Engineers, who have helped me in my endeavours to follow trends in membership and in education policy.

Book Review

Architectural Science, No. 2, edited by Professor Henry J. Cowan, A.M.I.Struct.E., etc. (Sydney: Academic Press Pty. Ltd., 1957.) 106 + xi pp., 11 in. × $8\frac{3}{4}$ in. Illustrated. 21s.

This volume represents a symposium of twelve lectures and an added written contribution arranged by the Sydney University Extension Board and is intended to supplement the post-graduate work of those occupied with architectural structures. While the publication is intended primarily for architects, there is much to interest also the structural engineer on aesthetic grounds as well as in mechanics and construction.

The section on Mechanics starts with traditional forms and proceeds to rigid frames and space frames. Aesthetics is the subject of the second section and presents the views of the architect, the teacher and the painter.

Construction is the title of the last section and here the topics range from the economics of high buildings to practice in relation to structural and architectural design, while the drafting of a modern structural code is the subject of the other article in this section.

Modern Methods of Fabricating Structural Steelwork*

By M. F. Palmer, M.I.Struct.E., M.I.C.E.,
and R. J. Fowler, B.Sc.(Eng.), M.I.Struct.E., A.M.I.C.E., A.M.I.Mech.E.

Synopsis

Fabricating processes in use to-day are mentioned and matters relating to many of these are discussed.

Some aspects of the more modern processes of flame cutting and electric-arc welding are given in fuller detail, particularly the contractions and distortions caused by these processes in structures.

The radiographic inspection of welds is stated to be of doubtful value, more importance being placed on the care taken when the actual welds are made.

Brief mention is made of the high strength bolt from the practical aspect.

The paper concludes by discussing the outlook based on more steel being available, and in a greater variety of forms.

Introduction

THE three main methods of joining steel to form structures are riveting, bolting and welding. It is possible to use each of these in almost any type of structure, although various advantages can be obtained by employing any one of them in certain circumstances. Table 1 summarises the possible methods of joining steel for the types of construction embodied in this paper. For shop construction of members and units, either riveting or welding is normally employed, and for connecting these together on site, riveting, welding and bolting are used.

The post-war development of High Strength Bolting is such that it is replacing site riveting and close-tolerance and barrel bolting and can also replace site welding. Less highly skilled workmen can fasten high strength bolts than are required for riveting or welding, but it is necessary that special requirements are met in regard to the tools employed by them.

The continued use of bolts does mean that skilled template makers and markers-off will still be required as heretofore for riveted construction, whereas for the wholly welded construction, these tradesmen are not so essential.

The steady growth in the use of electric-arc welding in shop fabrication during the last thirty years has meant a reduction in the number of riveters required, and consequently, firms as a whole have not needed fully to make good the normal losses in this trade. Since the last war, the tendency has been to construct heavy plate girders by means of welding, using flanges up to 3 or 4 ins. thick, but more recently, possibly owing to some doubts on the behaviour of these thick flanges in tension so far as brittle fracture is concerned, a few engineers are apparently reverting to riveted construction, using multiple plate thicknesses. Any appreciable swing back to riveting could cause serious difficulties, in view of the limited number of riveters at present available. There are signs, however, that the now greater availability of N.D.1., the notch tough steel to B.S.2762 most commonly used in structures, will ease this problem.

Fabricating Processes

The modern steel fabricating works which specialises in making bridges and heavy industrial buildings is not in the position of having to handle much work of a repetitive nature, whereas factories manufacturing motor vehicles, machine tools, railway locomotives and the like build appreciable numbers of identical units. The approach to the manufacturing problem of one is vastly different from that of the other.

When repetition occurs in structural steelwork, as it must to some extent, advantage is taken of methods which will enable similar parts to be produced as economically as possible. Examples of this are batch drilling using steel jigs, batch planing, and batch profiling using oxygen-gas. With the use of stops and registers on shears, planers, croppers, saws, etc., production of similar parts can be achieved without the necessity for individual marking out. The latest development in this direction is the special equipment which is used largely for the complete preparation of material for such parts as riveted beams and columns for multi-storey buildings. This is, however, more an application of automation to steelwork fabrication, rather than merely taking advantage of repetition.

Table 2 summarises the various operations which may be involved in the fabrication of a steelwork contract from the time that the design drawings are prepared to the time that the work is despatched to site. It will be appreciated from the table that many of the processes employed in modern steel fabrication are similar to those that have been in use from the birth of the industry. Notable advances have been made, however, in the speed of operation, capacity and accuracy of many of the machine tools. Gas cutting and arc welding are comparatively new operations, both of which have developed from the simple hand tools of thirty to forty years ago to fast precision tools. Machine gas cutting and electric arc welding are indispensable to steel fabrication to-day. The use of power hand tools is increasing for grinding and chipping operations, and their advantage is in their portability and high speed of cutting.

Preparation of Templates

The making of templates is a skilled operation,

* *Paper to be read before the Institution of Structural Engineers, at 11, Upper Belgrave Street, London, S.W.1, on Thursday, 27th November, 1958, at 6 p.m.*

Table 1

SYSTEMS OF CONSTRUCTION

Construction	Type of Shop Fabrication	Type of Site Connection*
TRUSSED	RIVETED	A.B.C.D. (All usually with Gusset Plates)
GIRDER	WELDED	A.B.C.D.F. (All usually with Gusset Plates) E. (e.g. Vierendeel Girders)
PLATE	RIVETED	A.B.C.D. (All usually with Cover Plates)
GIRDER	WELDED	B.C.D.F. (With Cover Plates) E. (No Cover or Splice Plates)
COMPOUND COLUMN AND BUILT UP COMPRESSION MEMBER	RIVETED	A.B.C.D. (All with Cover Plates)
	WELDED	B.C.D.F. (All with Cover Plates) D.F. (With End Plates) E. (No Cover or End Plates)

* A = Riveted, B = Close Tolerance Bolts, C = Barrel Bolts, D = High Strength Bolts.
E = Butt Welds, F = Fillet Welds.

Table 2

FABRICATOR'S PROCEDURE

(1) Preparation of Material Ordering Lists.
(2) Preparation of Workshop Drawings.
(3) Preparation of Fabricating Lists, Despatch Lists, and Calculated Weights.
(4) Preparation of Templates.
(5) Material Preparation—Operations.

(a) SIZING		(b) FORMING		(c) JOINING	
Bars & Sections	*Plates*	*Bars & Sections*	*Plates*	*Bolting & Riveting*	*Welding*
Straightening (Roller or Press)	Flattening (Roller or Press)	Cropping or Sawing for mitre bends & notches.	Bending Folding.	Punching.	Machine Planing Bevels & J preparations.
Cropping & Sawing to length.	Longt'l Rotary Shearing	Gas Cutting for mitre bends & notches.	Pressing.	Drilling single or multiple plates from timber or steel templates.	Oxygen Gas Planing Bevels.
	Machine Planing.				Hand Chipping by portable tool (pneumatic).
Gas Cutting & Grinding to length	Longt'l Oxygen Gas Slitting.				
	Guillotine Shearing.		Rolling curves & cones.	Drilling single or multiple plates from hard bushed steel jigs.	Hand Grinding by portable tool. (Pneumatic and high frequency electric).
	Oxygen Gas Planing & Profiling.	Slab & Presswork for joggling, bevelling, bending, flattening, spiralling, rounding.	EdgeSetting in rolls or press.		
	Grinding as required.		Scarfing for riveted joints	Countersinking.	
		Rolling curves & rings.		Tapping.	
		Hydraulic bending and setting.		Removal of drillings and burred edges.	

(6) Joining on Assembly of Parts.

Riveting	*Black Bolting*	*Close Tolerance & Barrel Bolts*	*High Strength Bolts*	*Welding*
Tack Bolting & Drifting.	Tack Bolting & Drifting.	Tack Bolting & Drifting.	Tack Bolting & Drifting.	Manual Tack Welding.
Reamering to fair holes as required.	Black Bolting.	Reamering holes to size through adjacent parts.	Torque Bolting.	Finish Manual or Automatic Welding.
Riveting— Hydraulic Pneumatic pressure ("squeeze") Pneumatic hammer		Bolting.		Removal of Weld Slag. Removal of Spatter. Grinding or Chipping ends of butt welds etc. Stud Welding.

(7) Ending and Machining.
(8) Works Trial Erection including reamering as required.
(9) Marking and Painting etc.

and their accuracy very largely governs the final accuracy of the structure. Templates are usually made of softwood, the steel being marked from them shortly after they are made before the timber has had time to shrink. Experience has taught template makers the necessity to check templates if they are re-issued to the works after a lapse of time. If a template is to be used many times over a long period, the fabricator may decide to make his templates in steel instead of timber, to be sure of maintaining accuracy, but it should be pointed out that initially the accuracy of both timber and steel templates is the same, since the same methods of marking out and drilling are involved. Steel templates are, however, expensive, and their use is not common.

In a number of cases, where only one or two of an item are required, and where otherwise suitable, the plater will mark his steel direct from drawings without the aid of templates.

Straightening and Flattening

The straightening of steel sections, which may take place more than once from the time that a member leaves the hot rolling mill to the time it is built into a structure, is usually carried out with the bar in the cold state. The process overbends the bar in the reverse direction to that in which it is deformed to allow for a certain amount of "springing back." The operation therefore involves stretching the material in the bar beyond its elastic limit.

The same principle is used in the flattening of plates, the process in this case being to pass the plates through a mangle in which a series of rollers are set so as to interfere slightly with each other, thus curving (i.e. stretching) the plate first in one direction and then in the reverse direction before it emerges.

Mangles can also be used to straighten long plates. In this case the final rolls are arranged so as to be capable of nipping the plates. In the rolling process, very thin shims are inserted along one edge of the plate, which thins the plate at that point, and therefore stretches it.

Plates which are too small to be rolled are hand flattened, local buckles being taken out by peening.

Plates over about 2 ins. thick are not flattened by cold rolling or mangling at the rolling mills. Such plates, in widths up to possibly 4 ft., and of thicknesses of 2-4 ins. are sometimes employed in large welded plate girders for bridgework, and gantry girders for heavy steel mill buildings. The plates may have corrugations or waves up to $\frac{1}{4}$ in. deep over a length of only a few feet. In these cases, it is necessary to heat the plates and flatten in a press whilst hot to take out the worst of the waves and to bring the plates to within $\frac{1}{16}$ in. of true flatness. For gantry girders which are fitted with rails on the top flanges to carry very heavy crane wheel loads, it is sometimes necessary to machine plane or skim the full length of the top flange plate over a zone about 3 to 4 ins. wide to ensure a perfect bearing of the flange plate on the web plate or web tongue plate in order to relieve the fillet welds connecting them from high compression fatigue stresses. Sections and plates can also be straightened by the local application of heat from an oxygen-gas welding torch applied in the correct place. This work should be performed by an experienced operator.

Bending and Forming

The internal radius of bends in plates to B.S.15 should be not less than twice the plate thickness for cold bending to avoid the risk of cracking.

Bent knees at the ends of stiffeners are not common to-day, but where they are used, the practice of forming them from the solid bar by smithing has virtually disappeared. This method is replaced by vee-cutting the outstanding leg of the angle or tee, cold or hot bending it to shape depending on its thickness, and arc welding the joint. The result is a more accurate stiffener with less distortion at the heel.

It should be borne in mind that when bars are curved to a radius, there is surplus of metal on the compression side and a considerable thinning of metal on the tension side. The compression edge will buckle and these buckles may not be completely removed by hot smithing. The tendency to-day, where the radius of curvature of a member is small in relation to the size of the bar, is to fabricate these members from profiled parts welded together.

Shearing

Shearing is a rapid and economical method of cutting plates. For straight cuts, guillotine machines are in use which will cut 1 in. plate 8 ft. long accurately in one stroke. Long plates may be slit lengthwise by making a series of cuts, or by the use of rotary or wheel shears mounted on a carriage which moves along the length of the plate. The latter will also cut bevel edges suitable for welding.

The quality of shearing varies with the efficiency of the machine. It has the effect of distorting the edge of the plate to a greater or lesser extent, depending on the state of the machine and the thickness of the cut member. A typical sheared edge is given in Fig. 1, which also shows a cross section through the sheared edge of the plate.

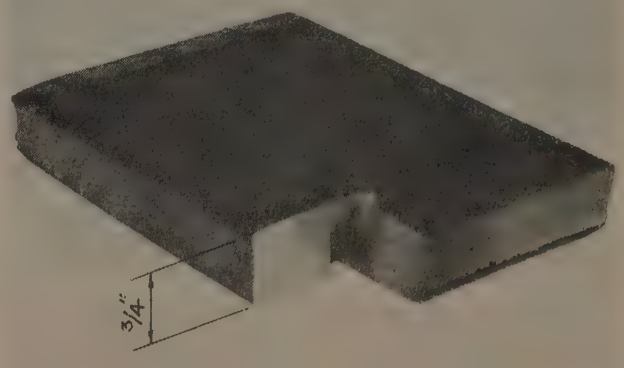


Fig. 1.—View on Typical Sheared Plate Edge and Cross Section

Flame Cutting and Gouging

In the structural fabricating industry, the application of the oxygen-gas torch has developed as a cutting and forming tool, and not as a welding tool. The most recent application is the long "straight-line" slitting machine, which operates with two or more burners. The small portable single burner straight-line cutting machine in which the track guiding the machine is laid on the actual plate to be cut, has been in common use for many years.

Since the war, the straight-line slitting machine has been employed by many firms in the industry for cutting

plates into narrower widths, which are frequently used for the flanges of welded plate girders. With this machine, long and truly parallel cuts are made. Fig. 2 shows a $2\frac{3}{4}$ in. thick plate for use as a flange of a heavy gantry girder being cut to 3 ft. wide with two burners operating, and Fig. 3 shows a face view of the resulting edge. Such a plate could be cut at a speed of 40 ft. per hour.

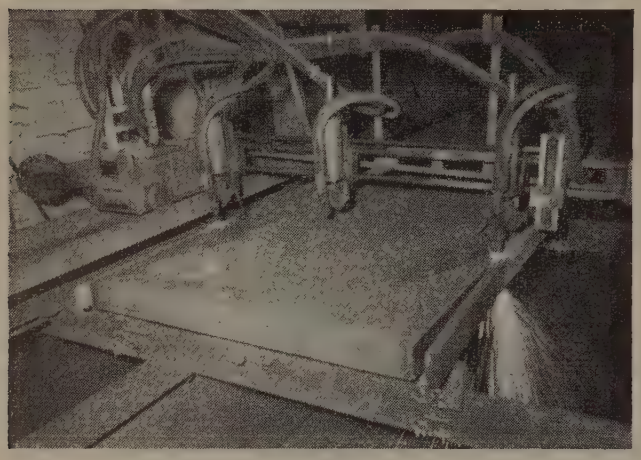


Fig. 2.—Oxy-Acetylene Straight Line Slitting Machine Cutting $2\frac{3}{4}$ in. Plate

Fig. 3.—View on Oxy-Acetylene Cut Edge

The new B.S.153 requires that plates in tension cut by this method shall be limited to 1 in. thickness, with no limit for plates in compression. It has been suggested that the reason for limiting the plate thickness for tension plates is that incipient cracking may arise in the cut edge. Such cracking is, however, related more to the nature of the plate material and its carbon content than to any other feature. Carbon content in this context is taken as including allowances for other elements present in the steel which enhance the effect of carbon. The authors know of no case where the oxygen-gas cutting process applied to steel to B.S.15, even on thicknesses of 3 in. or more, has caused incipient cracking, and further investigation is desirable on this matter. For oxygen-gas machine cutting, the safe limit of carbon content is taken to be 0.3% under all conditions of ambient temperature and humidity found in practice. The carbon content of structural steels normally used for bridge construction is much less than 0.3%, although it is to be regretted that B.S.15 does not specifically limit the carbon content.

With regard to the slight undulations visible in the gas cut edge, it is considered by the authors that the hazards due to this cause, with properly controlled machine cutting, are no greater than those arising on the surface of the steel itself as a result of the rolling process. Recent investigation has shown that the depth of drag lines on machine gas cut edges is less than 0.002 in., and that the transitions are quite smooth in section. In other words, the quality of the gas cut edge may be superior to that of the rolled edge, which latter has been acceptable for many years.

Other normal uses of machine flame cutting are plate profiling to any shape, and the preparation of bevels for butt welds, when a double bevel cut and root face cut can be made simultaneously with a three burner head. It should be noted that for long slitting cuts, or for bevel cutting, a floating head is used which maintains the cutting nozzles a constant distance from the plate surface to ensure a consistent cut should the plate be not quite flat.

Flame cutting the long side of a plate can cause almost as much distortion and contraction of the plate as would the equivalent amount of welding. Where both sides of a plate are cut simultaneously, distortion can be said to be negligible, but longitudinal contraction would still exist, this depending on the width of the plate after cutting.

The flame gouging tool is sometimes employed for forming the hollow or 'U' preparation for butt welds, and for removing root penetration runs before making the first weld run on the reverse side of a butt weld. It has been used for 'U' preparations for girder flange butt welds, and its use obviates the awkward handling and setting of long plates necessary when these preparations are carried out by machine. Weld preparations made by this means are cleaned up by grinding.

Bolting

The modern development under this heading is the previously mentioned high strength bolt, which is tightened to a pre-determined torque to cause tension in the bolt, and hence friction between the faying surfaces of the members forming the joint. Acting in this way, it replaces the hot driven rivet. Since the holes for this type of bolt are clearance holes, the minimum difference in diameters between bolts and holes being $\frac{1}{16}$ in. for bolts up to 1 in. diameter and $\frac{3}{32}$ in. for bolts above this size, the preparation for them is no more costly than for rivets.

Applying the torque to these bolts by means of hand spanners, calibrated in some manner to indicate the torque applied, is a slow and laborious process when a number of bolts have to be tightened. The authors favour the use of pneumatic impact wrenches, which have been found to be sufficiently accurate for practical purposes. One method which shows promise, and is a development of other "turn of the nut" procedures, is to use a small impact wrench stalling at say 350 lbs. ft. of torque, and then turning the nut a further pre-determined fraction of a turn using a larger impact wrench.

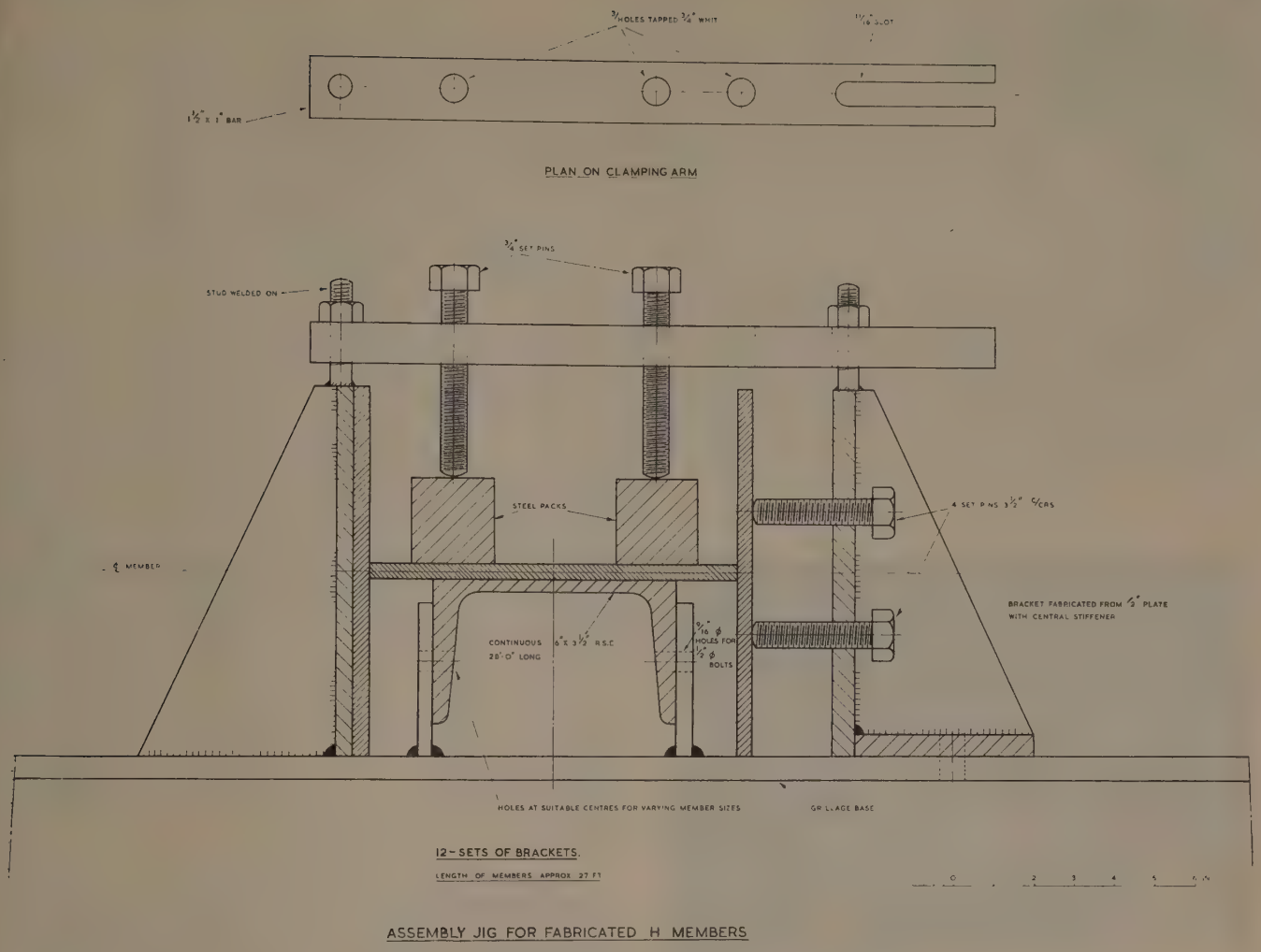

PLAN ON CLAMPING ARM
STUD WELDED ON
STEEL PACKS
BRACKET FABRICATED FROM PLATE WITH CENTRAL STIFFENER
HOLES AT SUITABLE CENTRES FOR VARYING MEMBER SIZES
12 - SETS OF BRACKETS.
LENGTH OF MEMBERS APPROX 27 FT
ASSEMBLY JIG FOR FABRICATED H MEMBERS

Fig. 4.—Assembly Jig for Fabricated H Members

Chipping and Grinding

Portable hand tools for chipping and grinding are widely used to-day in the preparation of material, and also to give the finishing touches to a job. A high rate of removal is obtained with the pneumatic chipping tool. This is frequently used for cutting weld preparations at the ends of rolled sections, for gouging out the back of the root runs of butt welds, and for the initial or rough removal of weld reinforcements where required. Where the heels of angle sections have to be shaped to nest into angle joint covers, the initial or rough cuts can be made with this tool.

The portable hand grinding tool has many similar applications, and is primarily a finishing tool, as the rate of removal is considerably less than with chipping, its purpose being to give a smooth, even finish.

Early grinding machines were pneumatically operated and used grit wheels, but to-day pneumatically operated machines using manufactured wheels are very largely used in constructional works. Electrically driven single phase 50 cycle machines are also used, the latest development in this field being 3 phase high frequency machines operating at up to 300 cycles. These last have a very high power to weight ratio, but owing to the special installation required, are in use only where items requiring a considerable amount of grinding are manufactured. The grinding wheels themselves have advanced in quality, and light resin bonded wheels down to $\frac{1}{8}$ in. thick operate safely at the highest speeds.

Workmen who are thoroughly experienced in the operation of portable chipping and grinding tools are able to achieve surprising neatness and accuracy in a great variety of applications, and thus help in attaining economic production. As a broad principle, however, grinding is an expensive operation, and should only be used where strictly necessary.

Welding

(a) *Preparation of Material*

It is now generally realised that by whatever method material is prepared for welded construction, the preparation must be accurately executed. Oversize and irregular gaps consume an excessive amount of weld metal, and consequently increase distortions and residual stresses, apart from adding to the cost. It is now usual to employ machined preparations, which include machine flame cutting wherever possible, to the exclusion of hand cutting, in order to ensure accuracy.

(b) *Welding Jigs*

A welding jig in principle is composed of a base or framework to which are attached locating and fixing or clamping devices, and is employed to ensure rapid and accurate assembly of a unit. The clamping device may be a lever, wedge, bolt or screw, or a clamp actuated by pneumatic or hydraulic pressure. These hold the component parts of the member being assembled accurately and securely in their correct relative positions for tack welding, and possibly also for complete welding. A typical jig of this type is shown in Fig. 4.

Alternatively, for large units, a system of heavy joists accurately levelled and bedded, or heavy cast iron plates, may be used to form a floor. To this floor may be attached suitable angle brackets, struts or other supports which, together with clamps, jacks, bolts, dogs, wedges, turnbuckles, etc., serve the purpose of the locating devices in the special purpose jig, such as is shown in Fig. 4. With this system of assembly, it is necessary for chalk string centre lines and plate positions to be struck on the meeting parts. Fig. 5 shows a large plate girder being assembled in this manner. A drawback to this latter method is that it is often necessary partly to assemble a member, and then to turn the member over to complete its assembly. This requires that a comparatively flexible unit must be crane handled, and great care may be necessary to ensure that tack welds are not broken or local damage caused to unstiffened component parts which may be difficult to rectify.

Fig. 5.—Large Plate Girder during Assembly in Shops. Length 110 ft. Weight 60 tons

(c) *Tack Welding*

During assembly a large amount of tack welding will be required, and it is important that tack welds are located carefully, and are of sufficient length and frequency to perform their duty.

Wherever possible, tack welds should be not less in size than the first run of finished weld, nor less than four times the thinner plate thickness in length, and the first weld run should be joined up with the tacks, and not deposited over them. Before commencing overlaying runs, the tack welds should always be inspected to ensure that any cracked or otherwise defective tacks are chipped out and properly made good.

(d) *Manipulators and Positioners*

Following the tack welding of an assembly, the individual welds are completed. This welding may be sufficient to complete the fabrication, or it may be a smaller amount which must be done before further assembly proceeds. Where possible, it is usually advantageous to undertake this welding in a manipulator or positioner. In such cases, general purpose equipment may be used which can be readily adjusted to receive units of varying dimensions. The main advantages of employing manipulators are that the work can be rapidly and economically turned over or positioned for welding so that faster welding techniques can be adopted, such as gravity welding instead of horizontal vertical and other "positional" welding, and that procedures and sequences can be more readily adopted which will ensure more accurate alignment of the finished job, i.e., reduced distortion.

Manipulation can be provided to give rotation on one axis only, or on two axes. It is usual in structural work to employ uni-axial rotation, since the assemblies are generally long members, and as such, are rotated about their longitudinal axis only, as shown in Figs. 6 and 7.

Fig. 8 shows a manipulator for welding butt welds in flanges for plate girders. The centre portion of the flange being welded is 14 in. × $2\frac{1}{2}$ in. plate and the end portions 14 in. × $1\frac{3}{4}$ in. plate. The welds are double "U", and the flange plate is rolled over on the rollers shown, from time to time, to permit welding alternately on opposite sides of the plate. By using careful judgment, flanges welded in this manner finish flat ready for incorporation in a girder. Similar flanges are shown incorporated in the plate girder standing beside the welders. In this case, the complete girder was assembled horizontally on bearers, the web butt welds having been made. These butt welds were vee welds prepared from the upper side only. The girder was then tack welded complete with stiffeners and while it was still in the horizontal position the welds to the stiffeners were completed. Where the flange to web welds are not too large, they may also be completed before turning over the girder for welding on the other side.

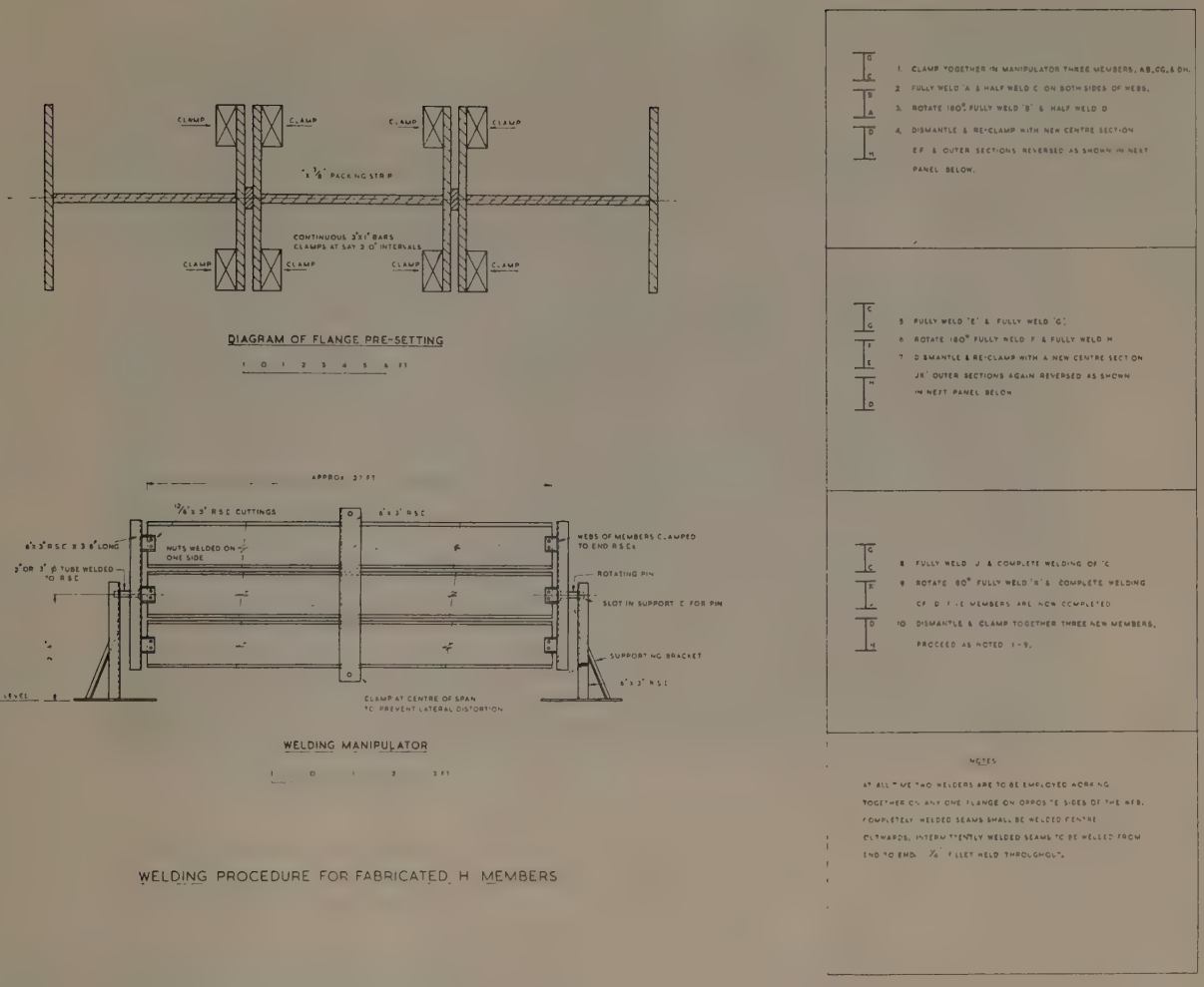
(e) *Automatic Welding*

Automatic welding has advantages in increased speed and in reduced distortion and cost over manual welding, in the welding mainly of heavy box sections, plate girders and stocky joist sections, but where stiffeners occur to interrupt its continuous run, manual welding becomes more practicable. Where plate girders are made with automatic welds between web and flanges, it is necessary to delay the assembly of web stiffeners until this welding has been completed. Both automatic welding and hand welding are equally satisfactory in any class of work.

(f) *Shrinkages and Distortions*

All welding produces shrinkages and distortions to a greater or lesser extent. Such shrinkages have to be allowed for especially in the lengths of members, and it is usual to do this by starting with overlong material and cutting the member to exact length after welding. Distortions can be very troublesome and require constant consideration in the design stage and during fabrication. There are two ways of dealing with an asymmetrical section; either it can be allowed to distort freely, the distortion being corrected by cold straightening afterwards; or it can be rigidly held during welding and cooling to prevent distortion. The method adopted depends on the nature of the work. The type of distortion in large girders which can be subsequently corrected is mainly confined to longitudinal bows. It is not generally practicable to remove local distortions in large members, but in sub-assemblies distortion can usually be corrected before they are welded into main members.

Distortion, whether it be from manual or automatic welding, is fundamentally of two forms, and will vary in extent according to the conditions obtaining. These forms are basically lateral and longitudinal contraction in the weld metal and in the immediately adjacent plate. Sometimes these contractions are contradictory


CLAMP
CLAMP
CLAMP
CLAMP
PACKING STRIP
CONTINUOUS 3"x1" BARS
CLAMPS AT SAY 2'0" INTERVALS
CLAMP
CLAMP
CLAMP
CLAMP
DIAGRAM OF FLANGE PRE-SETTING
APPROX 27'0"
12"x3" R.S.C. CUTTINGS
6"x3" R.S.C.
6"x3" R.S.C. x 3'8" LONG
NUTS WELDED ON ONE SIDE
2" OR 3" ϕ TUBE WELDED TO R.S.C.
WEBS OF MEMBERS CLAMPED TO END R.S.Cs
ROTATING PIN
SLOT IN SUPPORT E FOR PIN
SUPPORTING BRACKET
6"x3" R.S.C.
FLOOR LEVEL
CLAMP AT CENTRE OF SPAN TO PREVENT LATERAL DISTORTION
WELDING MANIPULATOR
1. CLAMP TOGETHER IN MANIPULATOR THREE MEMBERS, AB, CC, & DH.
2. FULLY WELD 'A' & HALF WELD C ON BOTH SIDES OF WEBS.
3. ROTATE 180° FULLY WELD 'B' & HALF WELD D
4. DISMANTLE & RE-CLAMP WITH NEW CENTRE SECTION EF & OUTER SECTIONS REVERSED AS SHOWN IN NEXT PANEL BELOW.
5. FULLY WELD 'E' & FULLY WELD 'G'.
6. ROTATE 180° FULLY WELD F & FULLY WELD H
7. DISMANTLE & RE-CLAMP WITH A NEW CENTRE SECTION JK OUTER SECTIONS AGAIN REVERSED AS SHOWN IN NEXT PANEL BELOW
8. FULLY WELD J & COMPLETE WELDING OF C
9. ROTATE 90° FULLY WELD K & COMPLETE WELDING OF D FIVE MEMBERS ARE NOW COMPLETED
10. DISMANTLE & CLAMP TOGETHER THREE NEW MEMBERS, PROCEED AS NOTED 1-9.
NOTES
AT ALL TIMES TWO WELDERS ARE TO BE EMPLOYED WORKING TOGETHER ON ANY ONE FLANGE ON OPPOSITE SIDES OF THE WEB.
COMPLETELY WELDED SEAMS SHALL BE WELDED FROM CENTRE OUTWARDS, INTERMITTENTLY WELDED SEAMS TO BE WELDED FROM END TO END. ⅜" FILLET WELD THROUGHOUT.

WELDING PROCEDURE FOR FABRICATED H MEMBERS

Fig. 6.—Welding Procedure for Fabricated H Members

Fig. 7.—Manipulator for Fabricated H Members

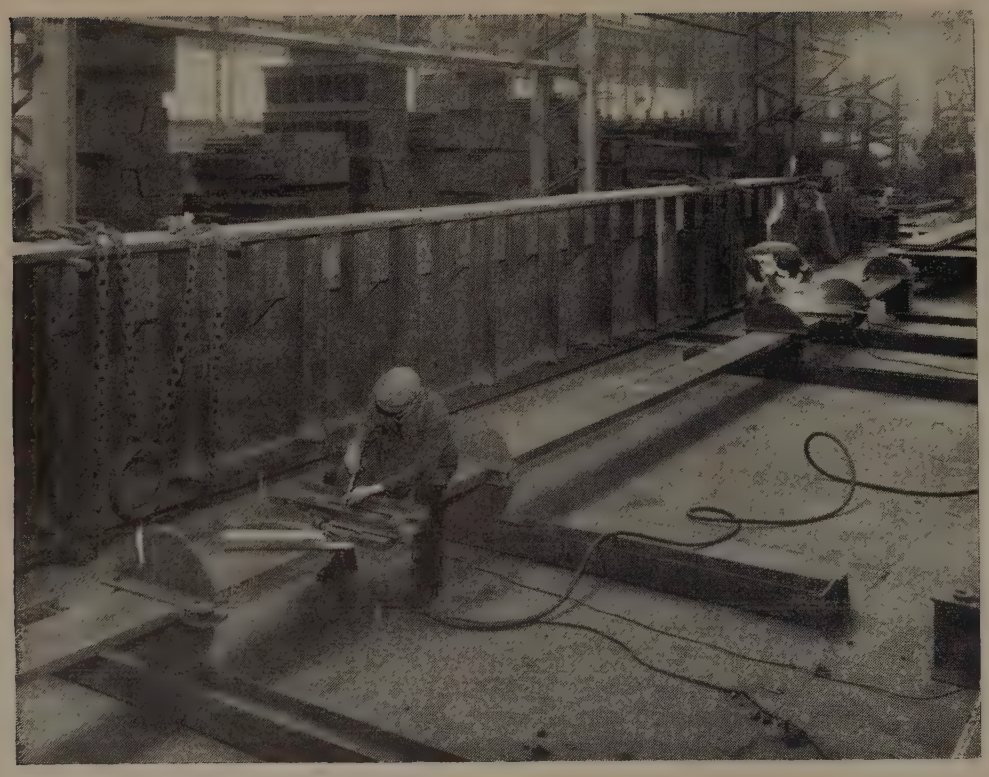


Fig. 8.—Manipulator for Butt Welding Plate Girder Flanges

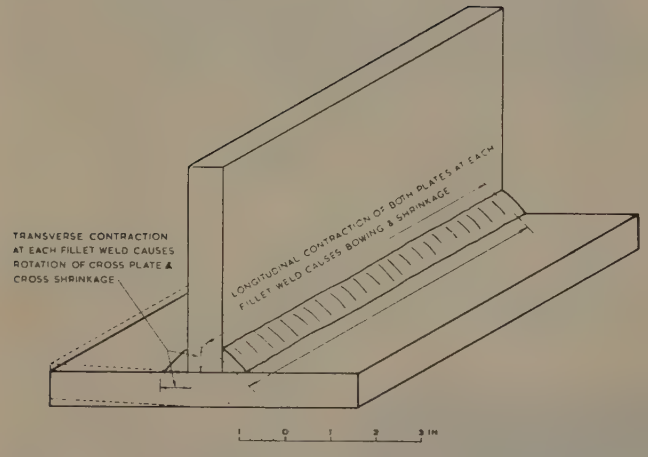

TRANSVERSE CONTRACTION AT EACH FILLET WELD CAUSES ROTATION OF CROSS PLATE & CROSS SHRINKAGE
LONGITUDINAL CONTRACTION OF BOTH PLATES AT EACH FILLET WELD CAUSES BOWING & SHRINKAGE
0 1 2 3 IN

Fig. 9.—Longitudinal and Transverse Weld Shrinkage

to each other, but this does not mean that the effects are completely cancelled out. A diagram illustrating these basic types of distortions is given in Fig. 9. Table 3 gives some examples of welding distortions and some possible treatments for them.

The following notes embody considerations which will help in controlling or eliminating distortions.

Some Hints on the Control and Reduction of Distortion

(1) *Keep welds to the minimum size that will safely transmit the loads to be carried. This requires correct design, specification and execution.*

(2) *Use the largest suitable size of electrodes, bearing in mind plate thickness, welding position, length of run, etc.*

(3) *Adopt a well thought-out welding procedure and run sequence. If this does not give a completely satisfactory result, it is at least known what has been done, and the appropriate changes can be made.*

(4) *Note that rigid restraint operates mainly against the plastic region of the weld during cooling, and so does not necessarily increase locked-up stresses. Considerable help can be obtained from the stress relieving of plates or components after preparation and before assembly, to eliminate the locked-up stresses which are always present in ordinary rolled material.*

(5) *Distortion may be counteracted by pre-setting or pre-bowing the parts out of their true position or angle prior to welding. The amount must be determined by previous experience.*

(6) *In certain cases, parts may be expanded by pre-warming before welding is commenced so that they contract with the weld metal. This will assist in reducing locked-up stresses in very rigid units.*

(7) *Peening of individual weld runs in heavy butt joints immediately after deposition of individual layers will reduce contraction. This operation should never be excessive and should be executed under the strict supervision of the Welding Engineer or Foreman. Final layers should never be peened.*

(8) *Where it is possible and economical, replace welds by bending plates.*

Table 3

SOME EXAMPLES OF WELDING DISTORTIONS AND THEIR TREATMENT.

COMPONENT	POSITION OF WELDS	TYPE OF DISTORTION	METHOD OF CONTROL
Thin Plates.	(1) All four edges. (2) On one edge.	(1) Centre bulges or buckles (2) Centre bulges or buckles to lesser extent. Both due to edge shortening.	Use step back welding sequence to break up additive heating and where possible fold plates instead of welding. Clamping restraint of little use.
Thick Plates.	Edges.	(1) Single bow of small amplitude or if weld small—no visible effect. (2) Transverse rotation of plate about joint if single vee butt weld.	(1) Weld from centre out. Preset plate with bow in opposite sense. (2) Use double vee butt weld or set plate out of angle in reverse direction by amount of anticipated rotation, or restrain physically.
Thin Plates.	Centre.	Buckling or rippling of edges.	Step back weld from centre out if joint is across plate, or stagger welding for a weld group at centre of plate. Clamping restraint of little use.
Thick Plates.	Centre.	Concave bow on side of welding with shallow stiffeners. Convex bow with deep stiffeners.	Pre-bow plate in opposite direction of bow and weld from centre out.
Thick and Medium Plates.	Stiffener to web connections.	Ribbing on face opposite stiffener.	Very difficult to avoid. Use staggered intermittent welding if possible. Conceal by locating stiffeners opposite each other.
	Flange to web connections.	(1) Longitudinal bowing of members (2) Folding of flange plate about web plate. (3) Longitudinal shortening.	(1) Balance welding to each flange by weld sequence. Pre-bow in opposite sense to resultant bow. (2) Pre-bow the flanges by strongbacks in opposite sense. Preset the flanges by rolling or bending in opposite sense. (3) Cannot avoid. Make appropriate allowance in lengths of unwelded plates, etc.
Member end connections.	All round one member.	Resultant connection is not truly at right angles.	(1) Balance weld. (2) Weld from outside of group towards centre to avoid build up of contraction lever arm.

Radiographic Inspection of Welds

(a) *Equipment*

In the post-war years there has been a steady increase in the requiring of radiographic inspection of welding, but whether or not this is an entirely satisfactory development is arguable.

Two types of radiographic equipment are employed for this purpose, X-ray and Gamma Ray. The former requires a comparatively large and bulky machine to transform the electric supply current to a high voltage and contain the head and controls, whereas the latter requires but a small source of radio-active material which is contained in a protective casing or bomb. Portable X-Ray machines are used now for works and site radiography, but with the disadvantage that their penetrative powers are limited to plate 1 in. to $1\frac{1}{2}$ in. thick with normal exposures. Gamma Ray equipment has some operational advantage in that it is readily portable and can be easily set up, but the exposure times required, thickness for thickness of metal, are many times greater than those required for X-Ray equipment. See Table 4.

Table 4

Examples of Exposure Times

The figures given below are for a constant Focal Length (F.F.D.) of 30″, using Kodak "Industrex D" Film with lead screens, and a density of 2.

The X-ray Unit is a Siemens 220 K 10 M.A. set and the Gamma source taken is $2\frac{1}{2}$ Curies of "Iridium 192."

M.S. Plate Thickness	X-ray	Gamma Ray
$\frac{3}{8}$″	$1\frac{1}{2}$ minutes	25 minutes
$\frac{1}{2}$″	$1\frac{1}{2}$ minutes	$27\frac{1}{2}$ minutes
$\frac{3}{4}$″	$2\frac{1}{2}$ minutes	31 minutes
1″	4 minutes	42 minutes
$1\frac{1}{2}$″	8 minutes	1 hr. 20 mins.
2″	14 minutes	2 hrs. 30 mins.

Note: Owing to the possible variables in the techniques, the above figures are approximate only, and are for the purpose of comparison.

The normal size of films in Great Britain is 15 in. × 4 in. and it is usual to adopt an effective length of 12 in. on each film, so that in this case one film is employed per foot run of seam photographed. The

exposure is made through the steel with the film located directly against the reverse side of the steel plate or weld. As the film is sensitive to light as well as radio-active sources, it is placed in a cassette which is impermeable to light rays.

Since for site work it is normally required that films should be developed soon after exposure, the provision of a mobile unit with darkroom and developing facilities which can be sent to sites is a decided convenience.

(b) *Scope and Value of Radiographs*

It is accepted that butt welds are suitable for radiographic inspection, whereas fillet welds are not. Only defects that are caused by defective workmanship are reliably detected, such as lack of root fusion and slag inclusions. Properly developed welding procedures, together with properly trained welding operators, will ensure freedom from deleterious welding defects. Weld cracks, which occur but very rarely and then usually only in rigidly restrained joints or in very thick plates, are detected by radiography only if they lie in the plane of the rays or nearly so.

Where radiographic inspection is required for shop welding, it is clearly desirable that it should take place on completion of welded sub-assemblies, rather than after the final welding of main assemblies. Thus, for plate girders, any butt welds in flanges or webs should be radiographed before these sub-assemblies are brought together so that any repairs found necessary may be carried out in as unrestrained a condition as possible. It should be noted that the condition of a repaired weld, which when originally made suffered from minor defects, may not be satisfactory due to the introduction of appreciable locked-up stresses.

The electrodes which were available for structural welding some twenty-five years ago deposited weld metal with numerous gas pockets and minor slag inclusions such as would not be accepted by inspecting authorities to-day; yet large fabricated structures, such as the Billingham Branch Bridge[1] with flange butt welds in 2 in. thick plate, have satisfactorily withstood many years of service.

Little investigational work has been carried out to indicate the influence of minor weld defects on the strength and service life of welded joints, and to the authors it seems that an excessive emphasis on clear radiographs, apart from causing unnecessary expense in radiographing, repairing the welds and re-radiographing, can react to the detriment of the job. Proper planning and supervision of the work will do more to ensure satisfactory results than post inspection by radiography.

Machining and Ending

Where it is necessary that members are finished to a true length it is normal practice to machine their ends, using a multi-toothed cutter. The member is set up carefully to ensure a truly square finish, and the cutter passes across at the appropriate speed. See Fig. 10. An obvious application of this tool is machining the abutting ends of stanchions and other compression members at splices. Here a truly square cut is essential. Similarly, stanchions are end milled to prepare them for bearing on a base plate. In the case of riveted stanchions, the main shaft, gusset plates, angle cleats and holding down bolt stools are all machined in one operation.

Due to the longitudinal shrinkage which occurs in welded members, such as plate girders, it is desirable, where they are required to be of true length, such as in gantry girders, to fabricate them with a margin over their length. They may then be gas cut to approximately $\frac{1}{2}$ in. over their final length and milled to true length. These stages are shown in Figs. 11, 12 and 13.

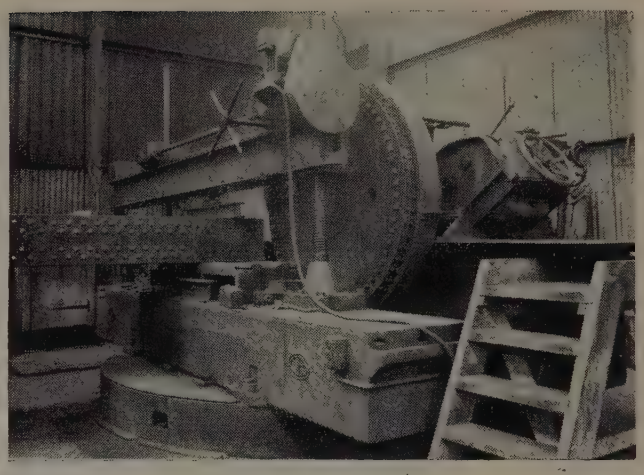


Fig. 10.—Ending Machine

Fig. 11.—Girder End Before Hand Gas Cutting to Approximate Length

Where there is difficulty in setting up large fabricated units for other machining operations such as drilling and boring, due to limited space around the fixed tools, portable machines are used which can be placed on the shop floor, or on the fabricated unit itself. These machine tools will require accurate locating and levelling in relation to the work-piece.

Fig. 12.—Girder End After Hand Gas Cutting

Fig. 13.—Girder End After Milling

Where it is required that a welded unit should be as stable as possible during machining, that is, that no movement due to the removal or release of locked-up welding stresses should occur, the unit should be stress relieved. This involves slowly heating the unit up to 650° C., soaking it at this temperature for one hour per inch of thickness, and cooling first in the furnace under controlled conditions, and then in still air.

Some recent trends and developments

The tendency to-day, in view of the high cost of labour, is to cut down workmanship to a minimum. This generally means using a greater tonnage of steel which is the reverse of the practice followed during the war and post-war years. The production of steel in this country is increasing, and the authors feel that the time has arrived when the cheapest and not necessarily the lightest steel structure is required.

We are approaching the state of affairs which has been ruling in the U.S.A. for a long time, and which is reported on fully by the Productivity Team which visited America in 1951[2]. This team found, inter alia, that a range of heavy rolled sections for columns and girders was available to the fabricator, which even in very tall buildings, avoided the need for compounding of sections. A special column section is rolled of 14 in. × 16 in. nominal section, which is available in 21 different weights per foot from 142 lbs. to 426 lbs. The lightest section has flanges $1\frac{1}{16}$ in. thick webs $\frac{11}{16}$ in. thick, whilst the heaviest section flanges are 3 in. thick and the webs $1\frac{7}{8}$ in. thick. This means that it is possible to use the same nominal column section from basement to roof, with comparatively small variations at splices.

The heavy girder sections, known as wide flange shapes, are rolled up to 36 in. × $16\frac{1}{2}$ in. × 300 lbs. per foot with $1\frac{11}{16}$ in. thick flanges and $\frac{15}{16}$ in. webs, differing weights of this same section being available down to 230 lbs. per foot. In the design of a steel framed building, efforts are made to keep the number of different sections used to a minimum, in order to reduce detailing and sorting in the shops, and also to fabricate as many of one item as possible to reduce production costs. The heavy girder sections are also used extensively as girders in bridge construction, the flanges being plated where necessary. Spans up to 90 ft. are possible on this basis, the very few stiffeners used improving the appearance and reducing the cost of the bridge.

A description has been published[3] of a new mill which is now in production in this country, and which adds to our broad flange beam production and extends its scope so that sizes comparable with those being rolled in the U.S.A. will be available to us.

So far as railway bridges are concerned, the tendency is to fabricate pieces as large as possible in the works so as to save time on the site. An example of constructing a railway bridge for despatch to site in large units is shown in Fig. 14. In this case, the bridge was assembled in the fabricating yard and the deck concreted in approximately 11 ft. square units. When the bridge was dismantled, these units, together with the three main girders, were sent to site, site connections being made with high strength bolts. A point of interest on this bridge is the almost complete absence of outside stiffeners to the outer girders. This arrangement materially assisted the fabrication of these welded girders, both practically and economically.

Fig. 15 shows a welded truss road bridge of 150 ft. span erected in the yard for inspection. All the web members were H sections built up by welding; these are also illustrated in Figs. 4, 6 and 7. The cross girders were plate girders of welded construction, the bottom flanges being in N.D.1 quality steel. The site connections were by high strength bolts, and Fig. 16 shows the connections at the intersection of the post and top chord. The construction of this bridge represents the latest development in the orthodox Pratt Truss.

Fig. 14.—Railway Bridge Assembled in Shops for Concreting Deck Units. Lengths - 58 ft. Weight of Steelwork – 55 tons

Fig. 15.—Yard Erection of 150 ft. Two Lane Road Bridge. Weight of Steelwork—75 tons

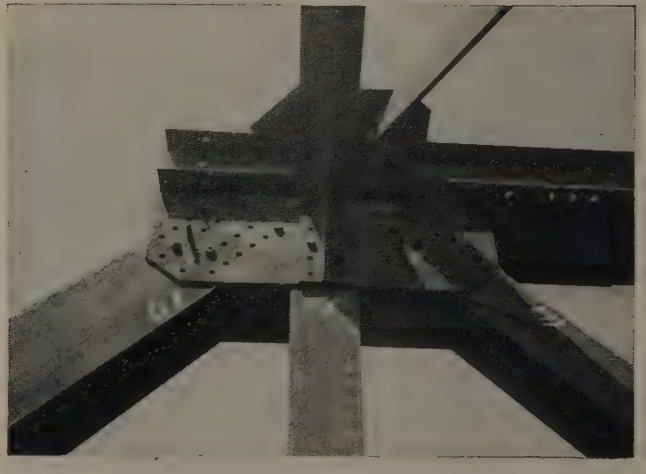


Fig. 16.—End Post and Top Chord Intersection Detail of Bridge in Fig. 15

NOTE

Both the Authors are members of the British Standards Technical Committee No. ISE/55—Girder Bridges (Steel) which has been reviewing B.S. 153, and some of the points mentioned in the paper were the subject of long discussions in Committee.

References

1 Billingham Branch Bridge. I.C.E. Paper by W. P. Haldane and G. Roberts. Proceedings 240 Page 537.
2 "Productivity Team Report on Steel Construction," July, 1952. Published by *Anglo-American Council on Productivity*.
3 Barlow, S. and Foster, G., "Universal Beams and their Applications." *The Structural Engineer*, November, 1957. (Discussion—April 1958).

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The Influence of Shear on the Moment of Resistance of Reinforced Concrete Beams

By K. Subbiah, B.E.(Andhra), M.Sc.Tech., and R. B. L. Smith, M.Sc.Tech., A.M.I.Struct.E.

Synopsis

The recommendations of British and other design codes on shear in reinforced concrete beams are examined and suggestions are made concerning the basis of an ultimate load approach. Some recent research and theories are discussed. Experimental results obtained by one of the authors are used, together with other published test results to develop equations for the moment of resistance of beams with or without web reinforcement. The physical significance of these equations is discussed and further research problems are outlined in relation to design requirements.

Notation

A_w	cross sectional area of stirrups
α	angle of inclination to horizontal of stirrups or bent-up rods.
b	breadth of beam
d_1	effective depth of beam
f	shear stress factor } as defined in
F	shear deterioration factor } the text
f'_c	crushing strength of 6 in × 12 in. cylinders
f_{yw}	yield stress in web reinforcement
f_y	yield stress in main reinforcement
k	neutral axis factor (ultimate) in simple bending
k_s	neutral axis factor (ultimate) with shear effects
k_1	ratio of average compressive stress in bending to $\frac{2}{3}u$.
k_2	ratio of depth to centroid of concrete compression in bending to k.
m	modular ratio
M_B	calculated failure moment in simple bending
M_L	shear compression moment according to Laupa
M_J	shear compression moment according to Jones
M_S	$F.M_B$ for beams without web reinforcement
M_{SW}	$F.M_B$ for beams with web reinforcement
M_T	test failure moment
n'	neutral axis factor by the elastic theory
q	shear stress by the elastic theory $= \frac{Q}{l_n b}$
Q	shear force
p_{st}	permissible stress in tensile reinforcement
r	ratio of tensile main steel $= \frac{A_{st}}{bd_1}$
r'	ratio of compressive steel
r_w	ratio of web reinforcement $= \frac{A_w}{bs \sin \alpha}$
s	pitch of stirrups along beam axis
t_s	stress in tensile reinforcement
x	shear span i.e. distance from support to nearest load
u	crushing strength of 6″ cubes
c_s	stress in compression reinforcement
E_s	elastic modulus of steel

Introduction

(a) Design methods based on ultimate load theory and tests have been introduced into design codes on reinforced concrete but at present these methods apply to the treatment of bending moments and axial compression, separately or combined, and the effect of shear is still treated by rules based on the " elastic " theory. The subject of this paper is the consideration of the combined effects of shear and bending, an understanding of which it is suggested is necessary for the proper use of ultimate load methods. For this purpose the strength of beams is expressed in terms of ultimate moment based on experimental evidence, instead of ultimate shear stress, since the effect of shear force influences the mode of bending failure and cannot be said to produce shear failure, except perhaps in the case of point loads very close to supports.

The British Standard Code of Practice CP.114 (1957) introduces " Load Factor " design with a cautious attitude to concrete failure (by the assumption of cube strength only $\frac{2}{3}$ of its actual value) thereby limiting the percentage of tensile main steel below the balanced section of ultimate load theory in bending. This is a useful safeguard against " shear deterioration," for test evidence reveals that the ultimate moment in shear and bending is adversely influenced by large ratios of main tensile steel. The expression " shear deterioration " requires explanation :— it signifies the fact that when a reinforced concrete section is subjected to combined shear and bending the full ultimate moment of resistance for bending only may not be realised, due to effects described in this paper.

(b) *Current design methods*

The present British Code of Practice specifies a value of the elastic shear stress $q = .033\ u$ (for $u >$ 3,000 lbs. per sq. in.) or $q = 40 + .02\ u$ (for $u >$ 3,000 lbs. per sq. in.) as the criterion of shear safety in a beam without designed web reinforcement, and four times this value as the limit for beams with web reinforcement. Other codes have similar recommendations although the interpretations of the significance of q vary considerably. An American code[1] permitted the use of higher values of q in cases where " special anchorage " of the main rods was provided, thus suggesting a realisation that end hooks to tensile reinforcement in beams constitute an extreme form of shear reinforcement. The German regulations are stricter than the others, not only in the values of q specified which are not linearly related to the concrete crushing strength, but also in the requirement that if any section of a beam exceeds the lower limit of q the whole of the shear throughout the span must be taken on reinforcement.

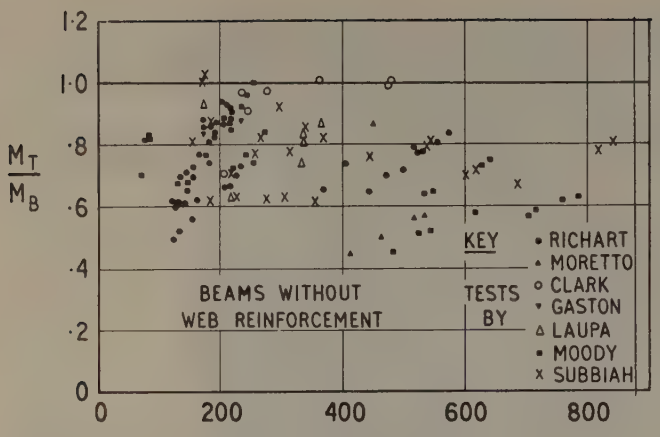

Fig. 1—q lb. per sq. in.

Fig. 1 indicates the range of failure values of q from test evidence of beams of normal concrete quality and it will be observed that in some tests very low failure values of q were recorded. All these beams were without web reinforcement and the majority of cases are not simple flexural failures as indicated by the fact that the ratio $\frac{M_T}{M_B}$ is less than 1.0 due to shear deterioration. It is sometimes stated that present-day Codes are unduly conservative concerning shear. This may be so in the majority of beams designed but Fig. 1 reveals that q is not a reliable criterion of shear capacity.

This philosophy of design assumes that diagonal cracking is equivalent to the failure of a section without web reinforcement and that such reinforcement when provided acts independently in resisting shear. A recent paper by Whitney[2] shows that the value of q at diagonal cracking is not a simple function of concrete strength, since it depends largely on the flexural reinforcement, and he proposed the following equation

$$q = 50 + 0.26 \frac{M_B}{bd_1^2} \sqrt{\frac{d_1}{x}} \quad . \quad . \quad (1)$$

based on test evidence. Much research has been devoted to evolving formulae to predict initial cracking but in the opinion of the authors, the precise definition of such cracking is practically impossible so that the personal element and test conditions will affect the reported cracking load. Once such diagonal cracks have occurred, the beam does not necessarily fail without considerable increase of load and at this stage q cannot represent an elastic shear stress. For this reason Whitney suggests that a nominal measure of shear intensity could as well be given by the shear force divided by bd_1, which is designated in this paper by the symbol f, and its significance is discussed later.

Hence the following conclusions are reached :—

(1) the only validity of q is to safeguard against diagonal cracking and this is questionable.

(2) beams designed without web reinforcement below the limit of q permitted by the Code may have widely varying load factors.

(3) the design of reinforcement when provided ignores the strength of the concrete section, or is assumed to act independently of it. Consequently efforts to assess the efficiency of such reinforcement give results inconsistent with the design theory[3].

(c) *Suggested basis of design*

Following the hypothesis outlined above, that the influence of shear affects the ultimate moment of resistance of a reinforced concrete section, consider first the capacity of a beam section in simple flexure, M_B, which would be required to be equal to working load moment multiplied by an appropriate load factor. (N.B. if a method is required in which the load factor is already introduced into the design formulae as in CP.114 (1957), it would be possible to carry out this modification, but it will not be considered further here). It is necessary to ensure that the beam will not fail below this moment M_B due to effects such as shear or lateral instability. It would also be desirable, though not essential, that M_B itself should result in yield of the tensile reinforcement rather than primary compression failure.

This approach would have the following advantages:—

(1) it would be economical since it would fully utilise the capacity of the section.

(2) it would give a guaranteed load factor which the present unrelated shear design method does not do.

(3) it would avoid the types of failure which occur suddenly and give no warning.

Shear does not directly cause the failure of reinforced concrete beams, but its effects appear as tensile stresses leading to cracks, which in turn influence the moment of resistance of the section. Hence it is convenient to develop ultimate load equations in terms of moment rather than in terms of shear in the form :—

$$M_{SW} = F.M_B \quad . \quad . \quad . \quad . \quad (2)$$

where F is a function of r, f_y, r', u, f, r_w and f_{yw}, with a maximum value of unity, to be described as the Shear Deterioration Factor.

All the variables listed represent properties of the cross-section with the exception of f, the ultimate average shear stress described above.

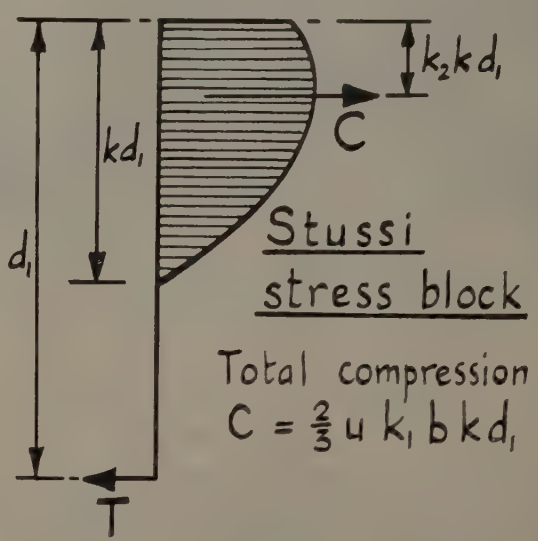

Fig. 2

The determination of M_B has been the subject of extensive research for many years and several methods have been developed which give similar results[4].

The stress block illustrated in Fig. 2 leads to the following equations :

Total compression $C = \frac{2}{3}k_1\, u.b.kd_1$

$= $ Total tension $T = rbd_1t_s$

Ultimate moment of resistance

$$M_B = C\ (1-k_2k)\ d_1$$

For beams with compression reinforcement the term $(r'bd_1c_s)$ must be added to the total compression. The factors k_1 and k_2 have been evaluated in relation to concrete cube strength. To derive a value for k in order to calculate M_B it is necessary to determine t_s and c_s. This is done on the basis of linear distribution of strain in the concrete section up to an assumed ultimate strain in the extreme fibre, usually taken between 0.3 and 0.4 per cent. From the resulting steel strains, t_s and c_s may be expressed in terms of E_S, with maximum values corresponding to yield or proof stresses. The procedure is therefore to assume both c_s and t_s equal to yield stress, determine k on this basis and then to check this assumption with correction if necessary.

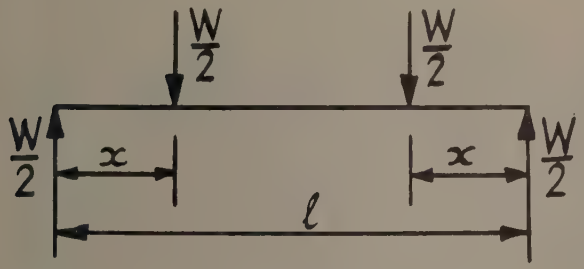

Fig. 3

The evaluation of the factor F for simply supported beams subjected to loading systems of the type shown in Fig. 3 is described later in this paper. Further research is in progress to extend its application to uniformly loaded and continuous beams and frames. It is of value in that it directly indicates whether the provision of web reinforcement is required and enables an adjustment of the area of web reinforcement to be made in order to increase F up to the value of unity. It has been found to apply to the whole range of available test data. Other expressions for the moment of resistance of reinforced concrete beams subjected to combined bending and shear force have been proposed[5,6,7], but the approach outlined above has two characteristic features :—

(1) it includes a shear intensity variable, f.

(2) it relates the moment with shear effects to the moment in simple flexure. This is considered to be of advantage for design purposes, but it should be made clear that the relation is based on calculated values of M_B not actual test values which may be on the average about 15% greater.

Earlier published research and theories

(a) The history of shear in reinforced concrete has been admirably exposed by Hognestad[8] and therefore only a few relevant topics will be discussed.

Early theories of shear, as advocated by the British and other design codes, were elastic in origin, as for example the formula for shear stress q, the truss analogy for design of web reinforcement (recommended for bent-up rods) and the elastic formula,

$$Q = \frac{A_w\, p_{st}\, l_a}{s}\ (sin\alpha + cos\alpha)$$

$$= K\, b\, l_a\, r_w\, p_{st} \quad . \quad . \quad . \quad . \quad (3)$$

where $K = (sin\alpha + cos\alpha)\ sin\alpha$

which is recommended by the British Code for stirrups, although it yields about $\sqrt{2}$ times the shear resistance given by the analogy (as usually interpreted) when both are applied to bent-up rods.

In 1927 Richart[9] suggested that the contribution of the concrete should be included in addition to the resistance of the reinforcement in the form

$$q = c + K\, r_w\, p_{st} \quad . \quad . \quad . \quad (4)$$

where $c =$ permissible shear stress on concrete

and this type of equation was endorsed by Wilby[3]. The American 1941 ACI Code adopted a formula of this type.

The elastic theory cannot be satisfactory as a basis of shear design. As long ago as 1909, Talbot[10] suggested an ultimate shear stress as a function of f'_c,r and the span of the beam. Various workers[11] have developed this idea after a long period of neglect, but none have produced an empirical formula satisfactory over a wide range. This failure is due to the conception of shear stress as a measure of shear capacity and to the fact that contributions of web reinforcement and concrete section have been treated as independent quantities to be added rather than as interacting variables.

(b) In 1953, Laupa, Siess and Newmark[5] published a new theory in which the attempt was made to treat the combined effects of flexure and shear on an ultimate load basis. According to this a beam may fail in one of four ways :—

(1) in flexure unaffected by shear[4].

(2) in "shear-compression." This is similar to to flexural failure except that the effect of shear tends to restrict the compression zone and lead to a lower moment than case (1).

(3) in "shear proper." This will only occur due to heavy loads very close to the supports and such failure has a different mechanism from (1) and (2). Little is known about this type of failure.

(4) A type of failure between (1) and (2).

From experiments of the type indicated in Fig. 3 in which x was the only variable[12], the conclusion was reached that the ultimate shear force was inversely proportional to x and that provided the failure is of type (2), the ultimate moment Wx/2 is a constant for a particular beam i.e. determined entirely by the properties of its cross-section. This moment value is called the "Shear-Compression" moment and is given by

$$\left.\begin{aligned} M_L &= f'_c\, b\, d_1^2\, k_s \varnothing\ (f'_c\, r_w f_{yw}) \quad \text{(Basic)} \\ &= f'_c\, b\, d_1^2\, (n' + mr')\left(0.57 - \frac{4.5}{10^5} f'_c\right) \\ &\quad \left(1 + \frac{2r_w f_{yw}}{10^3}\right) \quad \text{(Empirical)} \end{aligned}\right\} \quad . \quad . \quad (5)$$

It will be noted that the basic equation includes the term k_s which is replaced by $(n' + m_r')$ in the empirical equation.

This introduction of elastic factors is entirely a matter of convenience, but it tends to restrict the

formula to a limited range of application, even though the empirical terms were derived from all available test results.

The theoretical interpretation is open to several objections. The equation fails to reveal a reasonable value of k_s and makes the assumption that the concrete always fails in compression, which not only conflicts with experimental evidence, but also leads to difficulties concerning compression reinforcement. It is known that such reinforcement does not usually yield in failures of this kind (type (2)), and the modular ratio m is introduced in acknowledgment of this fact in equation (5) which is incompatible with a failure concept based on compression failure.

However, the principal objection to equation (5) is that it is based on the analysis of one type of failure, and on the assumption that ultimate shear is inversely proportional to x, which is approximately true only over a limited range.

A further limitation was discovered by Royston Jones[13] who applied Laupa's formula to his own tests and other tests carried out in the University of Leeds. He found it to be inaccurate above the range of concrete strength included by Laupa and proposed a modified formula on the same basis :

$$M_J = f'_c\, b\, d_1^2\, (n' + mr') \left(0.79 - \frac{9.74\, f'_c}{10^5} + \frac{4.02 f'^2_c}{10^9}\right) \left(1 + \frac{2 r_w f_{yw}}{10^3}\right) \quad . \quad . \quad . \quad .(6)$$

This equation is however less accurate than equation (5) for the range of concrete strengths up to 6000 lb. per sq. in. on which Laupa's work was based.

In spite of the above criticisms, the work of Laupa is of outstanding value in the study of shear effects in reinforced concrete beams. Its conception of the function of web reinforcement i.e. to restrict the development of diagonal cracks and so to force the beam to fail at its full flexural moment, is of great importance, and there is valuable discussion of the maximum useful quantity of web reinforcement.

Other topics discussed in the same paper include T-beams, restrained beams and the effects of other types of loading. In all these matters there is a serious lack of experimental evidence, which diminishes the present value of the conclusions reached.

Zwoyer[6] and Moody and Viest[7] have also developed ultimate moment formulae in combined bending and shear. Zwoyer accepts the concept of shear-compression in a similar manner to Laupa but this is disputed by Moody and Viest from experimental evidence. Both these equations are open to the same objection as applies to Laupa i.e. the effect of shear has not been included as a variable, the moment depending only on the properties of the beam cross-section.

Evaluation of the Shear Deterioration Factor F

The experimental research carried out in connection with this work included the testing of over 100 beams under the loading system of Fig. 3. These tests were intended

(a) to supplement the existing information from all available published sources which was used in this analysis.

(b) to gain experience from the study of modes of failure in actual tests.

It was observed that diagonal cracks in beams without web reinforcement lead to horizontal splitting

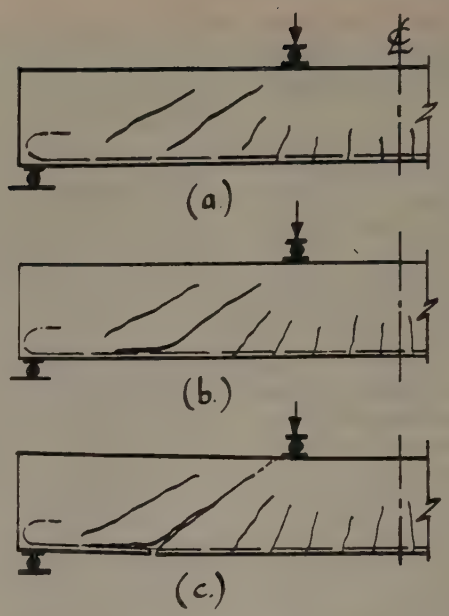

Fig. 4.—Stages in the failure of a beam by combined effects of bending and shear

along the tensile reinforcement as illustrated in Fig. 4, which in turn causes increased penetration of the compression zone by mechanical lever action. Stirrups may thus be seen to serve a double function (1) to prevent or restrict longitudinal splitting along the reinforcement, for which reason all practical beams should have some stirrups (2) to restrict the development of diagonal cracks which they cross, and this second purpose will also be achieved by bent-up rods from the main reinforcement. The effect of end anchorage hooks to the main tensile reinforcement may be understood as shear reinforcement, since their function is to prevent mechanical lever development of diagonal cracks near the ends of the beam.

The final failure of a beam with shear effects may be caused by extension of the horizontal splitting leading to bond failure, crushing of the concrete in the reduced compression zone, or, for high shear/moment ratios, shearing of the compression zone. In all these cases the failure is rather sudden, and provision of sufficient web reinforcement will prevent these types of failure and force the beam to fail in simple flexure.

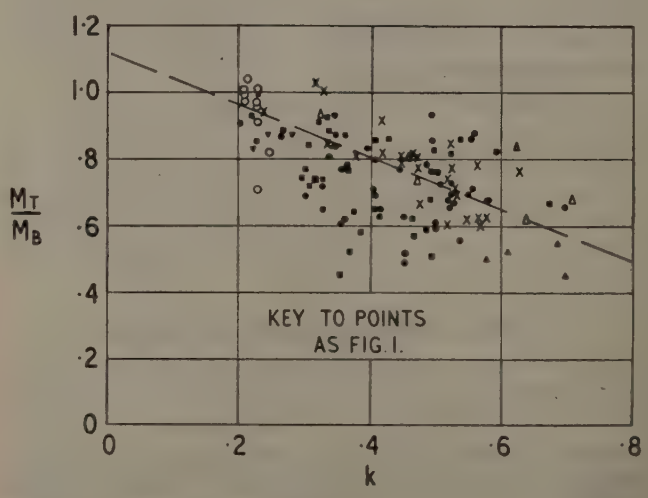

Fig. 5

(1) It was first necessary to consider beams without web reinforcement in order to study the resistance of the concrete section. Such results are liable to large scatter due to the longitudinal splitting described.

It is clearly a matter of great difficulty to isolate from a mass of test evidence the variables on which F was considered to depend, but by choosing a composite variable k, the neutral axis factor at ultimate load in flexure, itself a function of all the variables except the shear stress factor, and plotting the ratio $\frac{M_T}{M_B}$ from test results against k as shown in Fig. 5 a consistent relation was obtained.

The effect of the ratio $\frac{x}{d_1}$ was now investigated by plotting graphs of series of tests in which this was the only variable. This revealed a further relationship and an empirical equation was deduced in which F was given in terms of k and $\frac{x}{d_1}$. However, it was felt to be desirable to replace $\frac{x}{d_1}$ by a variable directly representing a shear intensity. The shear stress at failure moment M_T may be expressed as

$$\left(\frac{M_T}{x}\right)\frac{1}{b\,k_s\,d_1} = \frac{F\,M_B}{x\,b\,k_s\,d_1} = \left(\frac{F}{k_s}\right)\left(\frac{M_B}{b\,d_1^2}\right)\frac{d_1}{x} \quad . \quad (7)$$

neglecting the dowel action of the main reinforcement. This indicates that $\frac{x}{d_1}$ does not represent completely the effect of shear stress in the beam. $\frac{F}{k_s}$ is unknown but from test observations found to be approximately constant.

Consequently it was decided to define a shear stress factor,

$$f = \left(\frac{M_B}{b\,d_1^2}\right)\frac{d_1}{x} = \frac{M_B}{x\,b\,d_1} \text{ lb.} \times 10^3 \text{ per sq. in.} \quad . \quad (8)$$

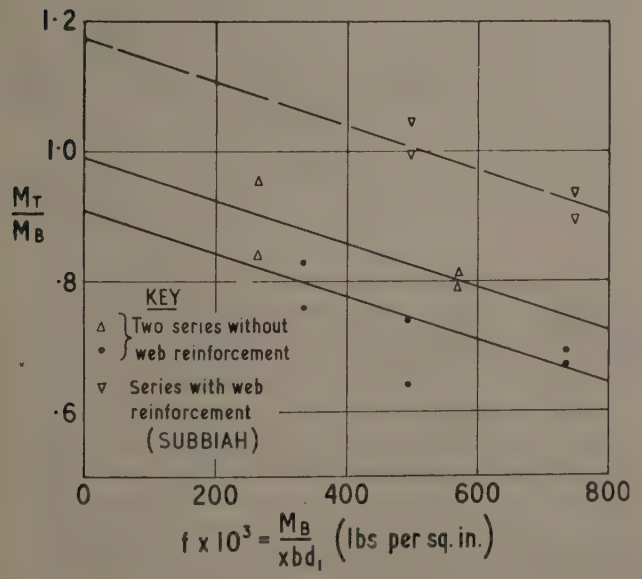

Fig. 6

Fig. 6 shows the result of plotting $\frac{M_T}{M_B}$ against f from tests in which f was the sole variable, and from this a trend expressed by $\frac{M_T}{M_B} = (1 - 0.3f)$ was observed. Clearly it would be desirable to have additional evidence on this.

Fig. 7 is a graph of $\frac{M_T}{M_B(1-0.3f)}$ against k from which the following empirical equation was deduced :

$$M_s = M_B\,(1 - 0.3f)\,(1.2 - 0.8k) \quad . \quad (9)$$

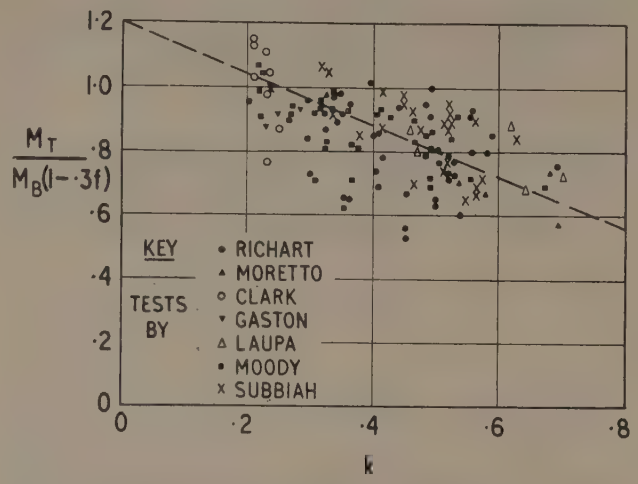

Fig. 7

The results of comparing this equation with various published tests are shown in Figs. 8, 9 and 10, and these show agreement $\pm$ 20% except for certain of Richart's tests in which bond failures are suspected.

(2) For beams with web reinforcement, it was assumed that the difference between M_s given by equation (9) and the failure moment in combined bending and shear was due to the provision of web reinforcement, and Fig. 6 indicates that the effect of the shear stress factor f may be the same for beams with as for without web reinforcement. Study of test data revealed that $(M_T - M_s)$ was proportional to M_B and $(1 - 0.3f)$, and Fig. 11 is a graph of $\frac{(M_T - M_s)}{M_B\,(1 - 0.3f)}$ against $r_w f_{yw}$, the trend of which has slope 1.8 so that

$$M_T - M_s = M_B\,(1.8\,r_w f_{yw})\,(1 - 0.3f)$$

i.e. $$M_T = M_{sw} = M_B\,(1 - 0.3f)(1.2 - 0.8k + 1.8 r_w f_{yw}) \quad . \quad (10)$$

where f_{yw} is in units of lb. $\times$ 10^3 per sq. in.

Since the maximum effective value of F is unity, there will be a limit to the useful ratio of web reinforcement. The group of 10 test results in Fig. 11 which lie to the right of the main group represent beams in which this useful limit has been exceeded.

The results of comparing equation (10) with various tests are shown in Figs. 12, 13 and 14. The high values observed for some of Moretto's tests may be attributed to the fact that the stirrups were welded.

It will be observed that the scatter of test results is reduced as compared with those for beams without web reinforcement, and this may be due to the elimination by the use of stirrups of the effects of horizontal splitting along the tensile reinforcement.

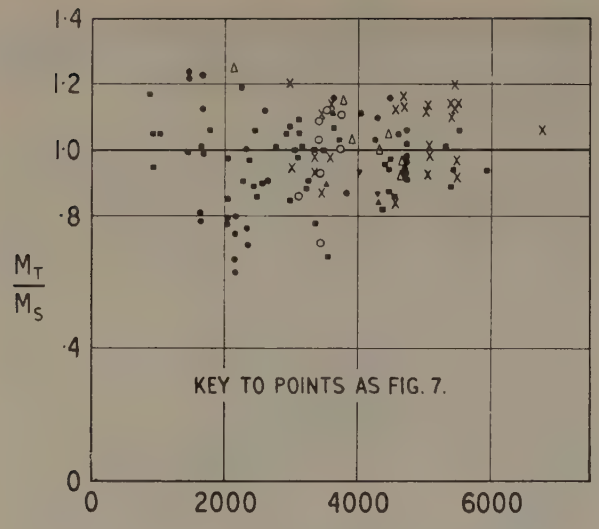

Fig. 8.—Concrete Strength f'_c, lb. per sq. in.

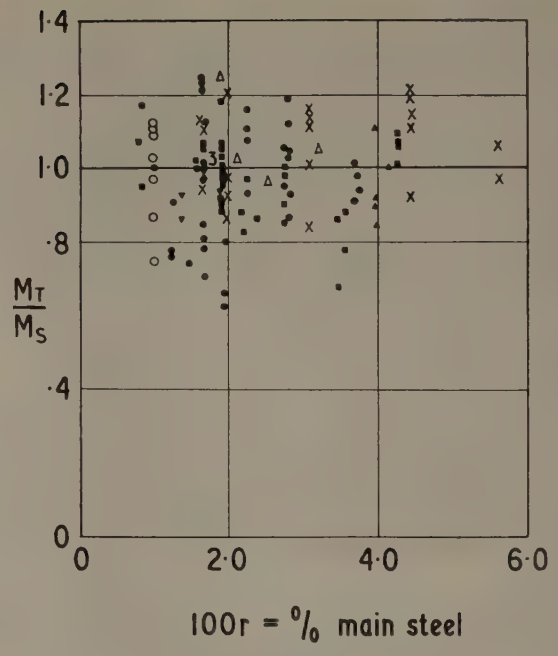

Fig. 9

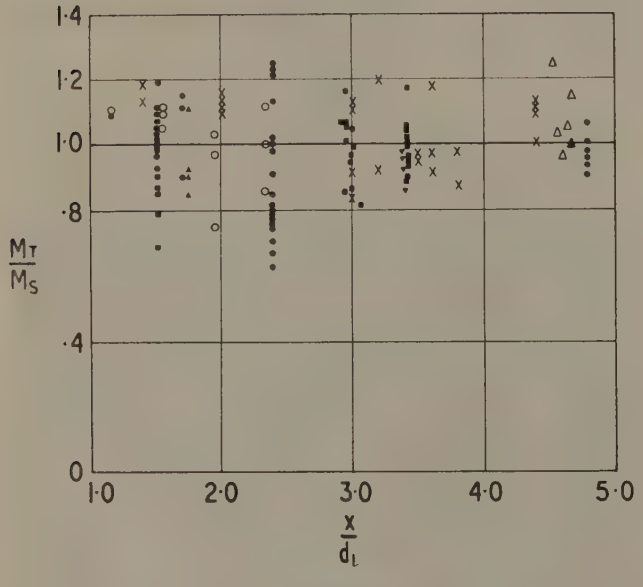

Fig. 10

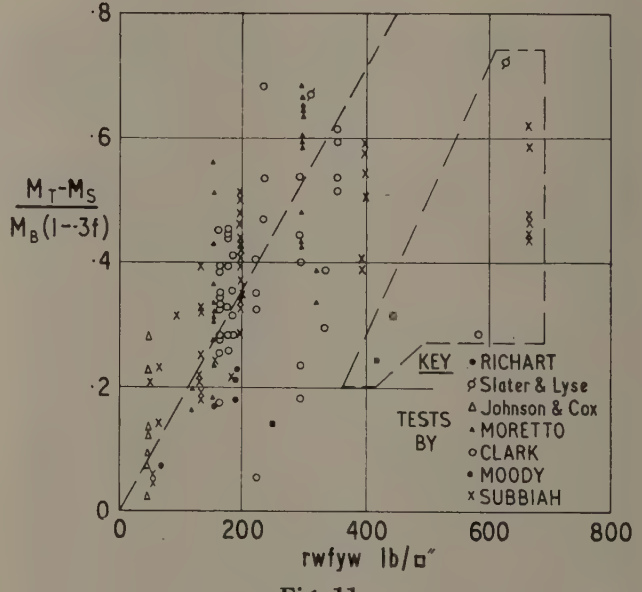

Fig. 11

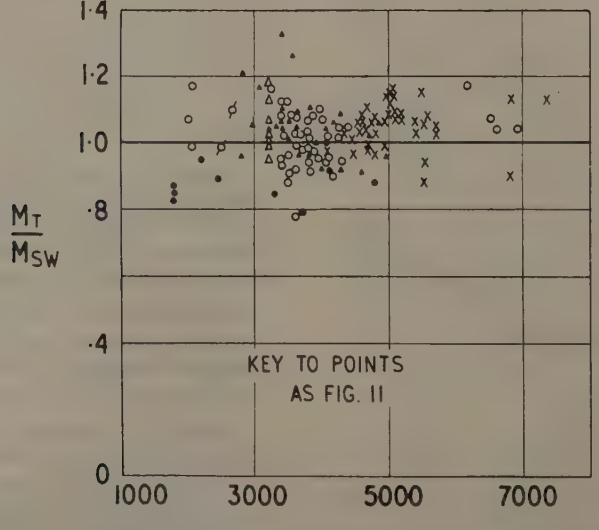

Fig. 12—Concrete Strength f'_c, lb. per sq. in.

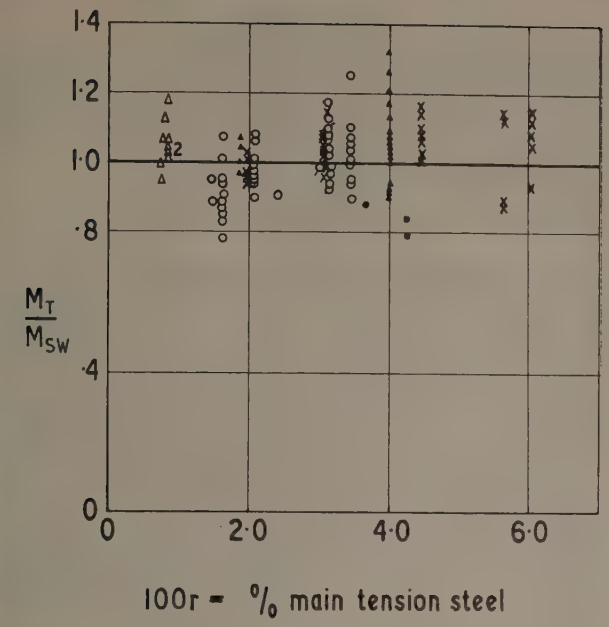

Fig. 13

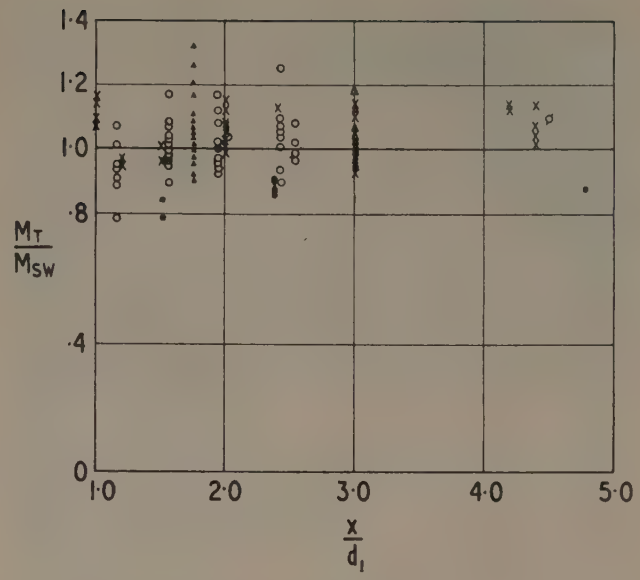

Fig. 14

Physical Significance

The factor F was considered to depend on three variables and it may be of interest to consider their physical significance :

(1) k, the neutral axis factor at ultimate load in flexure is a function of r, f_y and u. The extent of the penetration of the compression zone by diagonal cracks is affected by the value of k. Of course, beams with very small values of k will normally fail in simple flexure, and as k is increased, for example by the provision of more tensile reinforcement, a greater risk of shear failure is to be expected. The work of Laupa and others demonstrated that beams with high ratios of main tension steel are prone to shear failure not merely because they have high flexural moments of resistance, but also because of reduced shear capacity. The effect of this on k seems to be the most convincing explanation of this and hence it is reasonable to choose k as a function of F. This further demonstrates that present-day design practice of considering shear stress q only is unrealistic.

(2) f, an empirical shear stress factor. This would appear to be related to the extent of diagonal crack formation. Whitney[2] has suggested that shear strength depends on ultimate flexural capacity and ratio $\frac{d_1}{x}$. He concludes that it is therefore a function of reinforcement strength and beam proportions and not primarily dependent on u as assumed in the present conventional method. This contrasts with the theory of shear-compression moment (such as Laupa's) dependent on section properties only.

The difficulty lies in the definition of a shear stress factor to fit in ultimate load theory, since the ultimate shear is unknown until the ultimate moment also has been calculated, for which the factor is required. The method given above in effect postulates that the object of design is to make the ultimate moment in " shear-bending " equal to M_B, by web reinforcement if necessary. It cannot have design values greater than M_B. Hence the relevant ultimate shear is $\frac{M_B}{x}$, and the shear stress factor is $\frac{M_B}{x\,b\,d_1}$, for loading as in Fig. 3. In order to apply this to other cases of loading it will be necessary to establish the equivalent shear-span for each.

(3) $r_w f_{yw}$, the effective contribution of the web reinforcement. It may be noted that the assessment of the value of this contribution is almost the same as Laupa's. The action of stirrups is fundamentally to limit the extension of diagonal cracks (which is also done to some extent by the main tension steel, as noted in the question of end anchorage) and to prevent splitting along the tensile reinforcement. Good design practice insists on minimum web reinforcement in the form of " nominal " stirrups for all beams even though this is not required by the design code, and this is seen to be a wise provision. In restricting the development of diagonal cracks, the stirrups are thus effectively preventing a premature moment failure below M_B and thus forcing the beam to achieve its full flexural value.

Conclusions

In order that the treatment of shear should be made consistent with other aspects of modern ultimate load design in reinforced concrete, it is necessary to consider its effects in relation to the moment of resistance of a beam. An evaluation of the shear deterioration factor F has been described for a particular kind of load on simply supported beams.

The equations (9) and (10) give satisfactory agreement with test results over a considerably more extended range than previous equations such as (5) since for low values of f the moment approximates to M_B and as may be seen from the graphs, reasonable agreement is given even with cases treated as " shear proper " by Laupa, Siess and Newmark.

It is not possible at this stage to give a complete method of shear design based on the above treatment.

Since the majority of so-called " shear " failures are really failures in bending mainly differing from simple flexural failure in that the effect of shear causes the concrete to crack diagonally instead of vertically, it would be incorrect to consider a vertical section in applying equations (9) and (10). Instead the whole region of shear span should be reinforced to satisfy equation (10) at the section under the point load. Further research is required in order to apply this method to uniformly distributed loading, concerning which there was no available test evidence at the time of writing. The necessary values of M_B and k should be available in the form of charts or tables when ultimate load design becomes normal practice.

In the special case of point loads very close to the supports (very low $\frac{x}{d_1}$ ratios), available test evidence indicates that equations (9) and (10) are reliable down to $\frac{x}{d_1} = 1.0$. Below this value further experimental evidence is required.

In conclusion, the authors would refer briefly to the problem of frame design in reinforced concrete. It is clearly illogical to use an elastic frame analysis, such as moment distribution with section design based on ultimate load methods. Limit design of frames depends on the concept of plastic hinges or regions and it is necessary to ensure that such parts of the structure will not break down due to the increasing shear force associated with the development of plasticity. A paper by Khan and Mattock[14] describes an ingenious series of tests designed to simulate this effect. Their conclusion is that a plastic hinge subjected to increasing shear is at least as strong as a similar section in which the moment and shear are increased simultaneously to the same ultimate values. Since the principle of superposition could not be invoked for such a case, this conclusion is important. Half of the test beams were reinforced with stirrups sufficiently to make the calculated value of F greater than unity according to the method of this paper. The other half had no web reinforcement but although the calculated shear deterioration factor F is between 0.75 and 0.95, no reduction of full flexural moment was apparently observed. This suggests that further tests of this kind are desirable.

Acknowledgment

The work described in this paper forms the first part of a project on the combined effects of bending and shear in reinforced concrete members being undertaken in the Department of Structural Engineering, The Manchester College of Science & Technology. The authors are much indebted to Professor W. Merchant, M.A., D.Sc., S.M., M.I.Struct.E., A.M.I.C.E., for his encouragement and advice.

References

1 " Recommended Practice and Standard Specification for Concrete and Reinforced Concrete, Report of Joint Committee " *A.C.I. Journal*, June 1940.
2 Whitney, C. S., " Ultimate Shear Strength of Reinforced Concrete Flat Slabs, Footings, Beams and Frame Members without shear reinforcements," *A.C.I. Journal*, No. 4 Vol. 29, October 1957.
3 Wilby, C. B., " The strength of Reinforced Concrete Beams in Shear," *Magazine of Concrete Research* No. 7.
4 Hognestad, E., " A study of combined Bending and Axial Load," *University of Illinois Bulletin*, No. 399, 1951.
Report of ASCE—A.C.I. Joint Committee on Ultimate Strength Design (Paper No. 809) 1955.
Thomas, F. G., " Load-factor methods of designing Reinforced Concrete," *R.C.A. Review* Vol. III, No. 8, 1955.
5 Laupa, A., Siess, C. P., and Newmark, N. M., " Strength in Shear of Reinforced Concrete Beams." *University of Illinois Bulletin* No. 428, 1955.
6 Zwoyer, E. M. and Siess, C. P., " Ultimate Strength in Shear of Simply Supported Beams without Web Reinforcement " *A.C.I. Journal* October, 1954.
7 Moody, K. G. and Viest, I. M., " Shear Strength of Reinforced Concrete Beams Part 4—Analytical Studies," *A.C.I. Journal* March, 1955.
8 Hognestad, E., " What do we know about diagonal tension and web reinforcement in concrete?" University of Illinois.
9 Richart, F. E., " An investigation of web stresses, in reinforced concrete beams," *University of Illinois Bulletin* No. 166, 1927.
10 Talbot, A. N., " Tests of Reinforced Concrete Beams : Resistance to Web Stresses " *University of Illinois Bulletin*, No. 29, 1909.
11 Moretto, O., *A.C.I. Journal*, November 1945, Proc. Vol. 42 pp. 141-162.
Laupa, A., Siess, C. P., and Newmark, N. M., Civil Engineering Studies, *Struct. Research Series* No. 52, University of Illinois, April 1953. See also Ref. 10.
12 Clark, A. P., " Diagonal Tension in Reinforced Concrete Beams," *A.C.I. Journal*, October 1951, Proc. Vol. 48 pp. 145-156.
13 Royston Jones, " The ultimate strength of reinforced concrete beams in shear." *Magazine of Concrete Research* No. 23.
Discussion in Magazine of Concrete Research No. 25.
14 Khan, N. M. and Mattock, A. H., " An experimental investigation of the influence of the formation of a plastic hinge on the shear strength of a singly reinforced concrete beam." *Magazine of Concrete Research* No. 24, November 1956.

Book Reviews

Discovery No. 2—1957, by the University of Melbourne. (Melbourne University Press, 1957.) 96 pp., $9\frac{3}{4}$ in. × 7 in. 2s. 6d.

The second issue of this work appears after an interval of two and a half years. It includes twenty articles explaining research projects in the various departments of the University. The editors rightly suggest that the general reader will find much of interest in the book and have incorporated eighty illustrations to supplement the articles which cover such diverse subjects as Electricity in Medicine, Energy from the Sun, and ' Nylons and All That.'

The interest of structural engineers will probably centre on the section on Technology edited by Professor A. J. Francis, a Member of this Institution. This section features an article entitled ' Why Metals Fail,' and follows this with others on lubrication, industrial jewels and power control.

An Introduction to Automatic Digital Computers, by R. K. Livesley. (Cambridge University Press, 1957.) $8\frac{1}{2}$ in. × $5\frac{1}{2}$ in., 53 plus viii pp. 8s. 6d.

This is a brief account of digital computers which describes in general terms what they can do and how they are made to do it, and also gives some of the calculations for which they have been used. The emphasis is on the application of machines to routine compiling work rather than to research.

Institution Notices and Proceedings

THE PRESIDENT'S ENGAGEMENTS

NOVEMBER

Wednesday, November 5th, 1958

Wales and Monmouthshire Branch Opening Meeting, Cardiff.

Thursday, November 6th, 1958

South Western Counties Branch Opening Meeting, Plymouth.

FORTHCOMING MEETINGS

The following meetings will be held at 11, Upper Belgrave Street, London, S.W.1.

Thursday, November 13th, 1958

Ordinary Meeting at 6 p.m., when Mr. D. A. G. Reid, B.Sc.(Eng.), M.I.Struct.E., M.I.C.E. (Member of Council) will give a paper on "Technical Education and Professional Training."

Thursday, November 27th, 1958

Ordinary General Meeting for the election of members at 5.55 p.m., followed by an Ordinary Meeting at 6 p.m., when a paper on "Modern Methods of Fabricating Structural Steelwork" will be given by Mr. M. F. Palmer, M.I.Struct.E., M.I.C.E. and Mr. R. J. Fowler, B.Sc.(Eng.), M.I.Struct.E., A.M.I.C.E., A.M.I.Mech.E.

Thursday, December 11th, 1958

Ordinary Meeting at 6 p.m., when a paper on "The Design and Construction of Pelham Bridge, Lincoln" will be given by Mr. S. M. Reisser, B.Sc.(Eng.), M.I.Struct.E., A.M.I.C.E., Mr. D. Bolton, B.Sc.(Eng.), and Mr. K. M. Wright, B.Sc.(Eng.), A.M.I.C.E.

Thursday, December 18th, 1958

Ordinary General Meeting, 5 p.m. This meeting is for the election of members and is open only to corporate members of the Institution.

Thursday, January 8th, 1959

A Joint Meeting with the Institution of Highway Engineers will be held at 6 p.m., when Lt.-Colonel G. W. Kirkland, M.B.E., M.I.Struct.E., M.I.C.E. (Vice President) will give a paper on "Urban Motorways."

Thursday, January 22nd, 1959

An Ordinary General Meeting for the election of members will be held at 5.55 p.m., and will be followed at 6 p.m., by an Ordinary Meeting at which Mr. O. A. Kerensky, B.Sc., M.I.Struct.E., M.I.C.E., will give the first Maitland Lecture. The lecture is entitled "Modern Large Span Suspension Bridges."

Members wishing to bring guests to the Ordinary Meetings announced above are requested to apply to the Secretary for tickets of admission.

EXAMINATIONS, JANUARY, 1959

The Examinations of the Institution will be held in the United Kingdom and overseas on Tuesday and Wednesday, January 6th and 7th, 1959 (Graduateship) and Thursday and Friday, January 8th and 9th, 1959 (Associate-Membership).

EXAMINATIONS—JULY 1958, HOME CENTRES PASS LIST

The Examinations of the Institution were held in July 1958, at the usual centres in the United Kingdom. Seventy-five candidates took the Graduateship Examination and 384 took the Associate-Membership Examination. Of these, 41 passed the Graduateship Examination and 97 passed the Associate-Membership Examination.

The names of the successful candidates are :

GRADUATESHIP EXAMINATION

ASU-EZE, Sylvester.
ATHENDRIOU, Michael.
BARKER, John Barry.
BAYAT, Hassan Khaled.
BOGLE, John Brian.
BONSER, Donald Robert Martyn.
BURNETT-STUART, William.
BURROWS, Ronald Edward.
CUMBERLIDGE, Philip.
DIXON, Raymond James.
DUGDILL, Bernard Vincent.
EDLINGTON, Jack.
EDWARDS, Alun Jones.
FERRELLY, John Noel.
FORD, Ronald Francis.
FRASER, John Scott.
HALL, Peter William.
HOWARD, Douglas John.
JONES, Roy.
KALRA, Jagdish Chander.
MANNAVARAYAN, Sebamalai Loyolla.
MARTIN, Francois Regis.
MORTIMER, Cyril Paley.
MORTON, Howard.
MURPHY, Brian Christopher.
O'BRIEN, William Rex.
O'H-AISIDHE, Colm.
OLAOFE, Josephus Fola.
PAGE, Colin Frederick.
PATEL, Kantibhai Varadhbhai.
RIGBY, Francis Robert.
ROY, Mihir Kumar.
SADLER, Thomas John.
SANDHU, Iqbal Singh.
SEN, Tarunendra.
SIMPSON, Alan Jeffrey.
SOPER, Keith Barrie.
SYMONDS, Raymond Charles William.
TURNER, Brian.
WEBB, Ian Robin.
WILLCOCKS, Anthony John.

ASSOCIATE-MEMBERSHIP EXAMINATION

AFOLABI, Salawu Adewoyin.
APPLETON, Eric Walter.
AZZOPARDI, Godfrey.
BAILLIE, George.
BAIRD, Jack Alexander.
BELLAMY, Derek George.
BONE, Eric Walter.
BUCHER, Peter Emil.
BURTON, Michael Arthur Brian.
CHARMAN, William Royston.
CHOON ER KIAH.
COLE, Kenneth Frank.
COLLISTER, Frank.
COOKE, Donald Lewis.
COOPER, Michael Lloyd.
CORNS, Samuel Maurice.

Cosgrave, James.
Crease, Brinley.
Davies, David Oakley Mason.
Dean, Charles Michael.
DeLooze, Eric Norman.
Dew, Raymond William.
DuHeaume, Peter Learmonth.
Dunleavy, Sean Fergus.
Eadie, Douglas McDonald.
Elliott, Percy John.
Flint, John Michael.
Fraser, James Douglas.
Gerrie, Michael Bain.
Goodfellow, Reginald George.
Grout, Arthur Wilfred.
Guhabiswas, Satyendra Mohan.
Haines, Warwick Clive.
Hall, Wilfred Kenneth.
Hancock, John William.
Harkness, Brian Armstrong.
Harrington, James Joseph.
Helsby, Charles Michael.
Hemmings, John Richard.
Henderson, Keith.
Henderson, Stuart.
Hicklenton, Brian Stuart.
Hobbs, John Jennings.
Howarth, George Brian.
Huang Wei-Liang, Joseph.
Jamieson, Donald.
Johnson, Roger Paul.
Kennedy, Christopher David.
Ketteringham, Edward John.
Leadbeater, Geoffrey.
Lindop, John Furber.
Lister, Kenneth Francis.
McCaughey, John Donald.
McDonnell, Gerald.
Meakin, James.
Mercer, Horace John Gerald.
Millar, Malcolm Alexander.
Mookerjee, Malay Kumar.
Moore, Alan John.
Muller, John Roman.
Nelson, Harry Vincent.
Nicholas, Wilfred Arasaratnam.
Oliver, Jack Lewis William.
O'Loughlin, Eric William.
Omisore, Ezekiel Iyiola.
Ong Kok Ho.
Osborne, Michael Bryan.
Pedersen, Raymond Peter.
Pryke, John Fordham Speaight.
Ray, Samir Kumar.
Reay, Geoffrey Cecil.
Rimmer, William.
Robinson, John Anthony.
Roddick, John Gordon.
Sanyal, Salil Kumar.
Sen, Pabitra Kumar.
Sengupta, Prabhas.
Simpson, Brian.
Simpson, Frank.
Smith, Peter James.
Smith, Victor Francis Henry.
Spurgeon, Brian Anthony.
Stares, Arthur Robert.
Stebbings, Leslie George.
Sumner, Douglas Barrie.
Taylor, Brian.
Thei, Arthur Abraham.
Thorpe, Walter.
Tregilgas, William Gerald.
Ware, Allan Maurice.
Watkinson, Graham.
Welford, Paul Alexander.
Whittaker, Thomas.
Wild, John Patrick.
Williams, Ivor Frank.
Witkowski, Tadeusz Antoni.
Wood, Arthur.

THE A. E. WYNN PRIZE

Through the generosity of Mrs. A. E. Wynn, the widow of Mr. A. E. Wynn (Member), the Council has been enabled to establish a Prize to be known as the " A. E. Wynn Prize " in memory of her husband. The Prize will be awarded to the candidate in each Associate-Membership Examination who, passing the whole of the Examination, obtains the highest marks in the Reinforced Concrete Section of the Structural Engineering Design and Drawing paper. The first award of the Prize will be made in connection with the July 1958 Examination.

SYMPOSIUM ON HIGH STRENGTH BOLTS

The Council of the Institution of Structural Engineers have decided to hold a Symposium on High Strength Bolts and arrangements are now being made for this to be held at Church House, Westminster, on Wednesday and Thursday, 10th and 11th June, 1959. The Symposium will comprise technical sessions with discussion and also an exhibition of materials, equipment and photographs. The following subjects will be discussed at the technical sessions :

History, Research and Principles of Design
Bolts and Wrenches
Preparation of Steelwork and Site Erection.

Papers will be contributed by authorities of international reputation from European countries and the United States of America.

Details of the Symposium will be announced shortly.

THE MAITLAND MEDAL

As announced earlier this year, the Council have instituted a new award to be associated with the name of the Secretary, Major R. F. Maitland. The title of the award is " The Maitland Medal " and the general conditions governing it are as follows :

1. The Institution of Structural Engineers shall include hereafter in their Sessional Programme of Meetings a written lecture, to be known as The Maitland Lecture.

2. The subject of the lecture may be on research, design or construction in the field of structural engineering, with special reference to new developments.

3. Entrance into the competition will be open to all Members and Associate-Members of the Institution of Structural Engineers, but not Graduates or Students.

4. All papers received for the competition shall be submitted to assessors to be appointed by the Council and all such papers, including the prize winning lecture, shall be available for publication in the Journal of the Institution at the discretion of the Council.

5. No paper submitted shall have been published, or read elsewhere.

6. The winning lecture shall be presented at an Ordinary Meeting of the Institution in the early part of each Session.

7. The winner of the competition will receive the premium award to the value of £100. In addition,

he will receive the Maitland Silver Medal suitably inscribed, at a later meeting at which the Institution awards are normally presented.

8. In the event of there being no winner of the competition in any one or more years, whether because no paper submitted is considered to be of sufficient value to warrant award, or for any other reason, the Council shall retain the premium in their general funds.

9. The Council reserve the right, but not more than once in every three years, to invite an eminent engineer distinguished in the field of structural engineering to deliver the Maitland Lecture on a subject to be determined by the Council, in which case no competition will be advertised during that session, and the Maitland Medal and Premium will be presented to the lecturer.

(The Maitland Lecturer will not be eligible for any other Institution award or prize.)

THE MAITLAND LECTURE, 1958-1959

The Maitland Lecture will be given for the first time on the 22nd January, 1959, when, at the invitation of the Council, Mr. O. A. Kerensky (Member) will address the Institution on "Modern Large Span Suspension Bridges."

COMPETITION FOR THE MAITLAND MEDAL AND PREMIUM

Session 1959-60

The second Maitland Lecture will be given during the Session 1959-60. A Competition is being held and Members and Associate-Members of the Institution are invited to submit a written lecture in accordance with the conditions set out above. The winner of the Competition will be awarded the Maitland Silver Medal and Premium (value £100) and will present his Lecture early next Session.

All Lectures submitted for the Competition must be received by the Institution not later than the 1st March, 1959. Competitors are requested to submit five copies of their lectures.

SESSIONAL PROGRAMME 1959-60

The Literature Committee have under consideration the selection of papers for inclusion in the Sessional Programme for 1959-60. Members who may wish to offer papers are invited to communicate with the Secretary.

REPRESENTATION

The Council have appointed the following Institution representatives :

Nottingham Education Committee—Building and Civil Engineering Advisory Committee
Mr. E. R. Deeley (Member).
Mr. J. W. H. Chattaway (Member).
(To succeed Mr. L. G. Griffiths and Mr. A. N. Procter, who have resigned).

Hammersmith College of Art and Building—Governing Body
Lt.-Col. R. F. Galbraith (Past President)—re-appointed.

West Midlands Advisory Council for Technical Education—Civil Engineering Advisory Committee
Mr. W. H. Veal (Member).
(To succeed Mr. G. S. McDonald, who has resigned).

Loughborough College of Technology—Advisory Committee on Civil Engineering
Mr. G. F. Eley (Member)

OVERSEAS REPRESENTATIVES

The Council have re-appointed the following Overseas Representatives of the Institution for a further period of five years :

Australia
Victoria and New South Wales
Professor A. J. Francis (Member).
Queensland
Mr. E. Snowden (Associate-Member).

Canada
Dr. P. L. Pratley (Member).

Ceylon
Mr. N. Wynne-Jones (Member).

Hong Kong
W/Cdr. S. E. Faber (Member).

India
Bombay State
Mr. H. S. Batlivala (Member).

Israel
Mr. M. S. Gilutz (Member).

New Zealand
North Island
Mr. S. Irwin Crookes, Jnr. (Member).
South Island
Mr. C. W. Hamann (Member).

Rhodesia and Nyasaland (federation of)
Mr. K. G. Stevens (Member).

SPECIAL JUBILEE ISSUE OF "THE STRUCTURAL ENGINEER"

Copies of the Special Jubilee Issue of "The Structural Engineer" which was published on the 21st July to mark the Fiftieth Anniversary of the Institution are available, price 10s. 6d. (by post 12/-), on application to the Institution of Structural Engineers, 11, Upper Belgrave Street, London, S.W.1.

THERMAL INSULATION OF BUILDINGS

Thermal Insulation (Industrial Buildings) Act 1957 and the regulations issued by the Minister of Power under this Act come into operation on the 1st January, 1959.

The Act, regulations and an explanatory memorandum can be obtained from H.M. Stationery Office.

It will be recalled that in April of this year a conference on Thermal Insulation was held at Earls Court in connection with the Factory Equipment Exhibition when the objects and effects of this Act were expounded by a number of speakers.

A further conference on the same subject has been arranged in connection with the Factory Equipment Exhibition to be held in April 1959.

TERRITORIAL ARMY

Major R. H. C. Gates, M.C., R.E., A.M.I.Struct.E., Old Beech Cottage, Rectory Lane, Bracknell, Berks., will be interested to hear from members who would like to serve with the Territorial Army and in particular with 114 Army Engineer Regiment (T.A.) which is very short of officers and potential officers. The Headquarters of this Regiment is in Hackney, with Squadrons stationed at Tottenham, Holloway and Bethnal Green. It is one of the oldest units in the Territorial Army and has a proud record.

LONDON GRADUATES' AND STUDENTS' SECTION

Two visits to works were arranged during the summer months. The first took place on the 7th June, when members of the Section visited the Fulham Gas Works. The party's progress round the works followed the gas production sequence and began at the riverside, where the sea-borne mine coal was being unloaded from colliers and despatched to the works by a conveyor system approximately half a mile long. In the Converter House, the visitors saw the conversion process from crushed coal to raw gas. They then visited the Pump House. The gas storage holders proved interesting, one constructed in 1830 and reputed to be the oldest in the world, was still in use and in near perfect condition. Another nearing completion was of novel construction, the steel plated roof shell being supported by the gas itself once inflated.

An interesting visit to the Mortlake Brewery took place on the 9th August, when members were shown the impressive extension scheme now being carried out. The scheme comprises a five storey steel framed building with a 16 ft. deep cellar, and underground liquid storage chambers together with two tunnels, one 180 ft. long and a bridge connecting adjoining buildings. The work is being carried out in two phases ; the first, roughly half of the building, tunnels and bridge, is now complete with the plant being installed. The visit was the more interesting to see the completed first phase with the second phase in the course of construction.

The skeleton of the building was cased structural steelwork with insitu and prestressed plank floors, loadings varying from 2—6 cwts. per sq. ft. and with column loads of the order of 700 tons requiring piled foundations. Only the towpath separated the cellar and pile cap excavations from the river, which twice flooded the site.

Following the delivery of the steelwork to site various amendments had become necessary, requiring larger openings in the floors and heavier floor loads, etc. The Consultants used the modern device of reinforcing the steelwork with reinforced concrete and reinforced concrete trimmer beams. Also floor areas had become inadequate and it was decided to place the corridor 10 ft. wide on each floor outside the steel framework. These were supported on post tensioned reinforced concrete cantilevers anchored back to the steel frame.

The steel frame involved some 1,400 tons of steel for both phases. There were approximately 250 tons of reinforcement, six miles of prestressed planks and 25,000 sq. yds. of mesh. The total cost of the works is estimated at £750,000 excluding plant.

The following meetings have been arranged and will be held at 11, Upper Belgrave Street, London, S.W.1, at 6.30 p.m. :

Tuesday, November 4th, 1958

Engineers' Forum.

Speakers : D. N. Mitchell, M.I.Struct.E., M.I.C.E., M. E. R. Little, M.A., A.M.I.Struct.E., A.M.I.C.E., J. E. C. Wehrle, A.M.I.Struct.E.

Monday, December 1st, 1958

Films of Engineering Interest.

Tuesday, January 13th, 1959

Address by a Vice-President of the Institution.

Hon. Secretary : R. M. Amodia, B.E., 21, Wetherby Gardens, London, S.W.5.

Branch Notices

LANCASHIRE AND CHESHIRE BRANCH

The following meetings have been arranged :

Tuesday, November 11th, 1958

Dr. C. T. G. Boucher, M.S.(Tech.), A.M.I.Struct.E., A.R.I.B.A., on " A History of Structural Engineering in Lancashire and Cheshire."

Wednesday, December 3rd, 1958

Joint Meeting with the Reinforced Concrete Association.

Mr. W. S. Watts, A.M.I.Struct.E., A.M.I.C.E., on " Points of Structural Interest at Calder Hall."

Tuesday, January 13th, 1959

Mr. Clifford E. Saunders, M.I.Struct.E., (Vice-Chairman Western Counties Branch) on " Some Structures Involving Unusual Design Problems."

Meetings will be held at the College of Science and Technology, Manchester, commencing at 6.30 p.m., preceded by refreshments.

MERSEYSIDE PANEL

The following meeting has been arranged :

Wednesday, November 19th, 1958

Mr. N. T. Barrett, B.Sc.(Eng.), A.M.I.Struct.E., on " Housing the Dounreay Fast Reactor."

At the College of Building, Clarence Street, Liverpool, commencing 6.30 p.m. Light refreshments will be available from 5.30 p.m.

Joint Hon. Secretaries : J. L. Robinson, A.M.I.Struct.E., 314, Northenden Road, Sale, Manchester ; M. D. Woods, A.M.I.Struct.E., 8, Dennison Road, Cheadle Hulme, Cheshire.

MIDLAND COUNTIES BRANCH

The following meetings have been arranged :

Wednesday, November 12th, 1958

Dr. F. W. Gifford, M.I.Struct.E., A.M.I.C.E., on " Factory Production of Precast Concrete."

At the Electricity Demonstration Hall, Irongate, Derby, commencing 6.15 p.m., preceded by tea from 5.30 p.m.

Tuesday, November 25th, 1958

A Joint Meeting has been arranged with the Nottingham, Lincolnshire and Derbyshire Architectural Association, to be held at 64, St. James' Street, Nottingham, at 7 p.m.

Friday, November 28th, 1958

Joint Meeting with the Birmingham and Five Counties Architectural Association.

Mr. A. G. Ling, B.A., F.R.I.B.A., M.T.P.I., will give a talk on the " International Union of Architects 1958 Congress in Moscow."

Friday, January 23rd, 1959

Joint Meeting with the Reinforced Concrete Association.

Mr. A. P. Mason, B.Sc.(Hons.), M.I.Struct.E., M.I.C.E., (Honorary Librarian) on " Some Modern Examples of Reinforced and Prestressed Concrete Work."

Unless otherwise stated meetings will be held at the James Watt Memorial Institute, Great Charles Street, Birmingham, at 6.30 p.m. Tea will be served from 5.45 p.m.

Hon. Secretary : John R. Chaffer, M.I.Struct.E., 107, Jockey Road, Sutton Coldfield, Warwickshire.

GRADUATES' AND STUDENTS' SECTION

The following meetings have been arranged :

Friday, November 7th, 1958

Dr. L. G. Booth, D.I.C., on " Advanced Ideas in Timber Structures."

Friday, December 5th, 1958

Mr. H. C. Husband, B.Eng., M.I.Struct.E., M.I.C.E., M.I.Mech.E., (Honorary Editor) will introduce a sound film of the history and construction of " The Jodrell Bank Radio Telescope."

Friday, January 9th, 1959

Mr. S. M. Cooper, A.M.I.Struct.E., will give a talk and film show on " The Failure of the Tacoma Narrows Bridge."

All meetings will be held at the Birmingham Exchange and Engineering Centre, Stephenson Place, Birmingham, commencing at 6.30 p.m., preceded by tea from 6 p.m. Visitors will be welcome.
Hon. Secretary : F. A. Butterworth, " Roscrea," Tansey Green, Pensnett, Brierley Hill, Staffs.

NORTHERN COUNTIES BRANCH

Alteration of Meeting Date : Owing to unforeseen circumstances which arose after the Sessional Programme had gone to press, it was necessary to put forward the date of Professor Cassie's lecture on " Settlement Problems in Mexico City " from the 4th November (as announced) to the 28th October, 1958.

The following meetings have been arranged :

Wednesday, November 5th, 1958

At Newcastle. Mr. W. L. Day, O.B.E., A.M.I.Struct.E., on " Nuclear Power Stations."

Tuesday, December 2nd, 1958

At Middlesbrough. Mr. D. R. Sharp, M.B.E., B.Sc., A.M.I.Struct.E., A.M.I.C.E., on " Concrete Roads—Some Recent Developments."

Wednesday, December 3rd, 1958

The above paper will be repeated at Newcastle.

Wednesday, January 7th, 1959

Joint Meeting with the Northern Architectural Association.

At Newcastle. Mr. W. H. G. Durose, M.I.Struct.E., on " The Relationship between Contractors and their Clients."

Wednesday, January 14th, 1959

Joint Meeting with the Tees-Side Branch of the Institution of Civil Engineers.

At Middlesbrough. Mr. P. C. G. Isaac, B.Sc.(Eng.), M.I.C.E., F.R.S.H., on " Roman Public Works Engineering."

Meetings in Middlesbrough will be held in the Cleveland Scientific and Technical Institution, and meetings in Newcastle will be held in the Neville Hall. Buffet tea is served at 6 p.m., and meetings commence at 6.30 p.m.
Hon. Secretary : H. W. Dowe, A.M.I.Struct.E., 2, The Crescent, Saltburn-by-the-Sea, Yorks.

NORTHERN IRELAND BRANCH

The following meetings have been arranged :

Tuesday, November 11th, 1958

Mr. A. H. K. Roberts, B.A., B.A.I., M.I.Struct.E., M.I.C.E.I., A.M.I.C.E., will be installed as Chairman and will give an address entitled " The Chairman presents . . . . ".

Tuesday, December 2nd, 1958

Mr. J. McClure, B.Sc., A.M.I.Struct.E., A.M.I.C.E., will give a " Report on the Third International Congress on Prestressing, Berlin, May, 1958."

This meeting will be attended by the members of the Northern Ireland Association of the Institution of Civil Engineers.

Tuesday, January 6th, 1959

Dr. K. C. Rockey, A.M.I.C.E., A.M.I.Mech.E., on " The Design of Plate Girders."

Meetings will be held at the College of Technology, Belfast, at 6.45 p.m., unless other notification is given.
Hon. Secretary : L. Clements, A.M.I.Struct.E., A.M.I.C.E., A.M.I.Mun.E., 3, Kingswood Park, Cherryvalley, Belfast.

SCOTTISH BRANCH

The following meetings have been arranged :

Tuesday, November 4th, 1958

Mr. C. M. Wilson, M.I.Struct.E., M.I.C.E., on " Structural Steel Framework and Overhead Gantries at Leith Fertiliser Works for S.A.I. Ltd."

At the Adelphi Hotel, Coburn Street, Edinburgh, commencing 6.15 p.m.

Tuesday, November 25th, 1958

Joint Meeting with West of Scotland Branch, The Institute of Welding.

Mr. David Watson on " Application of Welding to Structural Engineering."

Tuesday, December 9th, 1958

Mr. K. F. Geesin, M.I.C.E., on " Structural Aspects of Ravenscraig Melting Shop."

Tuesday, January 20th, 1959

Mr. A. R. Dykes, B.Sc., A.M.I.Struct.E., A.M.I.C.E., on " Field Investigation of some Engineering Structures."

Unless otherwise stated meetings will be at The Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, commencing at 7 p.m.
Hon. Secretary : W. G. Cantlay, B.Sc., M.I.Struct.E., A.M.I.C.E., 3, Blairbeth Terrace, Burnside, Glasgow.

SOUTH WESTERN COUNTIES BRANCH

The following meetings have been arranged :

Thursday, November 6th, 1958

Mr. E. W. Howells, M.I.Struct.E., will give the Chairman's Address. At the Grand Hotel, Plymouth, at 7 p.m.

Friday, December 5th, 1958

Mr. Walton Lund on " The Construction of the new Queen Elizabeth Dock at Falmouth."

The meeting will be in Truro at a time and venue to be notified.

Friday, January 9th, 1959

Joint Meeting with the local branch of the Institution of Civil Engineers.

Mr. M. Holmes, B.Sc., A.M.I.C.E., on " Strength of Lattice Girders."

At the Duke of Cornwall Hotel, Plymouth at 6 p.m., preceded by tea from 5.30 p.m.
Hon. Secretary : C. J. Woodrow, J.P., " Elstow," Hartley Park Villas, Mannamead, Plymouth, Devon.

WALES AND MONMOUTHSHIRE BRANCH

The following meetings have been arranged :

Wednesday, November 5th, 1958

At Cardiff. Mr. Wallace A. Evans, M.I.Struct.E., will give the Chairman's Address.

Monday, November 10th, 1958

The Chairman's Address will be repeated at Swansea. *Since the Sessional Programme went to press it has unfortunately been necessary to alter the date of this meeting, which was originally announced to be held on Wednesday, 12th November.*

Saturday, November 15th, 1958

The Chairman's Address will be repeated at Colwyn Bay.

Friday, December 12th, 1958

Joint Meeting with the Institution of Civil Engineers and Institution of Municipal Engineers.

At Cardiff. Professor B. Neal, M.A., Ph.D., A.M.I.C.E., A. Harvey, Ph.D., and Lt.-Col. A. Borlase, T.D., M.I.C.E., will present a Symposium of Papers on " The Education and Training of a Civil Engineer."

Wednesday, January 7th, 1959

At Swansea. Films showing works of interest to structural and civil engineers, to be followed by a discussion.

Note : This meeting was originally announced for Wednesday, 14th January, 1959.

Thursday, January 22nd, 1959

Joint Meeting with the Institution of Municipal Engineers.

At Colwyn Bay. Mr. C. D. C. Braine, B.Sc., M.I.Struct.E., M.I.C.E., on " The Design of a Sea Outfall."

Meetings at Cardiff will be held at the South Wales Institute of Engineers, Park Place, commencing at 6.30 p.m. Meetings at Swansea will be held at the Mackworth Hotel, High Street, commencing at 6.30 p.m. The time and place of meetings at Colwyn Bay will be notified.

Hon. Secretary : K. J. Stewart, A.M.I.Struct.E., A.M.I.C.E., 15, Glanmor Road, Swansea.

WESTERN COUNTIES BRANCH

The following meetings have been arranged :

Thursday, November 20th, 1958

Joint Meeting with the Institution of Civil Engineers.

Mr. M. Holmes, B.Sc., A.M.I.C.E., on " The Strength of Lattice Girders."

Friday, December 5th, 1958

Mr. G. R. Caines (Student) on " Modular Planning in the Drawing Office."

Mr. J. R. Daniell on " The Measurement of strain by an electrical method."

Friday, January 2nd, 1959

Professor A. W. Hendry, D.Sc., Ph.D., M.I.Struct.E., M.I.C.E., on " Model Analysis of Structures."

Meetings will be held in the Small Lecture Theatre, University Engineering Laboratories, University of Bristol, commencing at 6 p.m., preceded by tea at 5.30 p.m.

Hon. Secretary : A. C. Hughes, M.Eng., A.M.I.Struct.E., A.M.I.C.E., 21, Great Brockeridge, Bristol, 9.

YORKSHIRE BRANCH

The following meetings have been arranged :

Wednesday, November 12th, 1958

At Leeds. Mr. G. B. Godfrey, A.M.I.Struct.E., A.M.I.C.E., A.M.I.Mun.E., (Associate-Member of Council) on " Tubes and Hollow Sections."

Wednesday, December 3rd, 1958

At Sheffield. Mr. F. J. Samuely, B.Sc.(Eng.), M.I.Struct.E., M.I.C.E., on " Precast Concrete Structures with particular reference to Folded Slab Roof Construction."

Wednesday, December 10th, 1958

At Leeds. Mr. S. Barlow, M.I.Struct.E., and Mr. G. Foster, A.M.I.Mech.E., on " Universal Beams and their Application."

Wednesday, January 21st, 1959

At Leeds. Mr. N. T. Barrett, B.Sc.(Eng.), A.M.I.Struct.E., on " Housing the Dounreay Fast Reactor."

Meetings at Leeds will be held at the Metropole Hotel, King Street, and meetings at Sheffield at the Royal Victoria Hotel. Meetings will commence at 6.30 p.m., preceded by buffet tea at 6.15 p.m.

Hon. Secretary : W. B. Stock, A.M.I.Struct.E., 34, Hobart Road, Dewsbury, Yorks.

UNION OF SOUTH AFRICA BRANCH

Hon. Secretary : A. E. Tait, B.Sc., A.M.I.Struct.E., A.M.I.C.E., P.O. Box 3306, Johannesburg, South Africa.

During weekdays Mr. Tait can be contacted in the City Engineer's Department, Town Hall, Johannesburg. Phone 34-1111, Ext. 257.

Natal Section Hon. Secretary : J. C. Panton, A.M.I.Struct.E., A.M.I.C.E., c/o Dorman Long (Africa) Ltd., P.O. Box 932, Durban.

Cape Section Hon. Secretary : R. F. Norris, A.M.I.Struct.E., African Guarantee Building, 8, St. George's Street, Cape Town.

EAST AFRICAN SECTION

Chairman : R. A. Sutcliffe, M.I.Struct.E.

Hon. Secretary : K. C. Davey, A.M.I.Struct.E., P.O. Box 30079, Nairobi, Kenya.

SINGAPORE AND FEDERATION OF MALAYA SECTION

Chairman : Mr. T. Karmakar.

Hon. Secretary : Mr. W. N. Cursitor, B.Sc., A.M.I.Struct.E., c/o Redpath Brown & Co. Ltd., P.O. Box 648, Singapore.

Acting Hon. Secretary : Mr. Chin Fung Kee, Department of Engineering, University of Malaya, Singapore 10.

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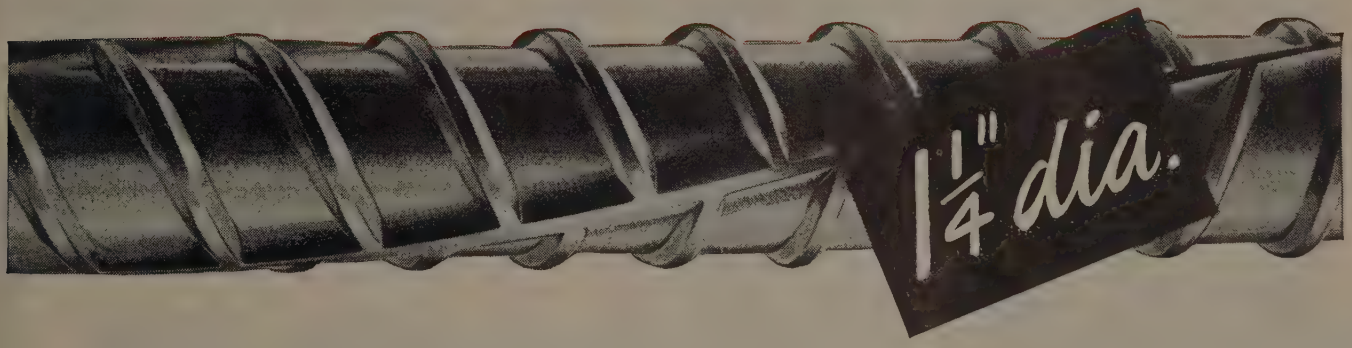

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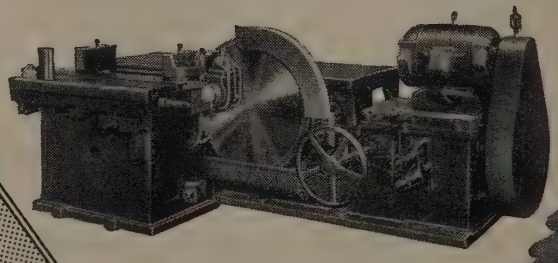

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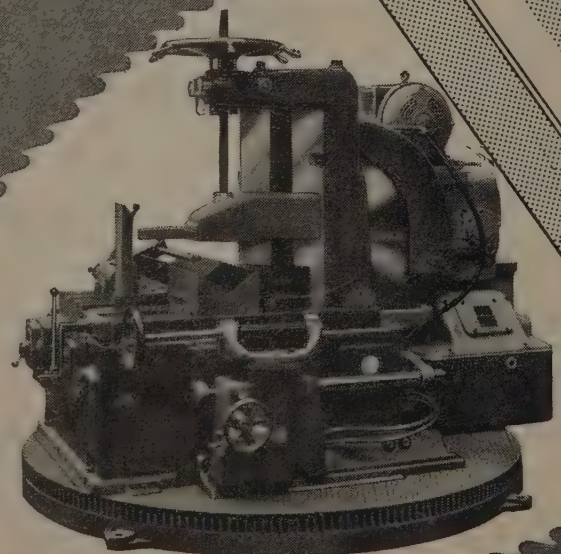

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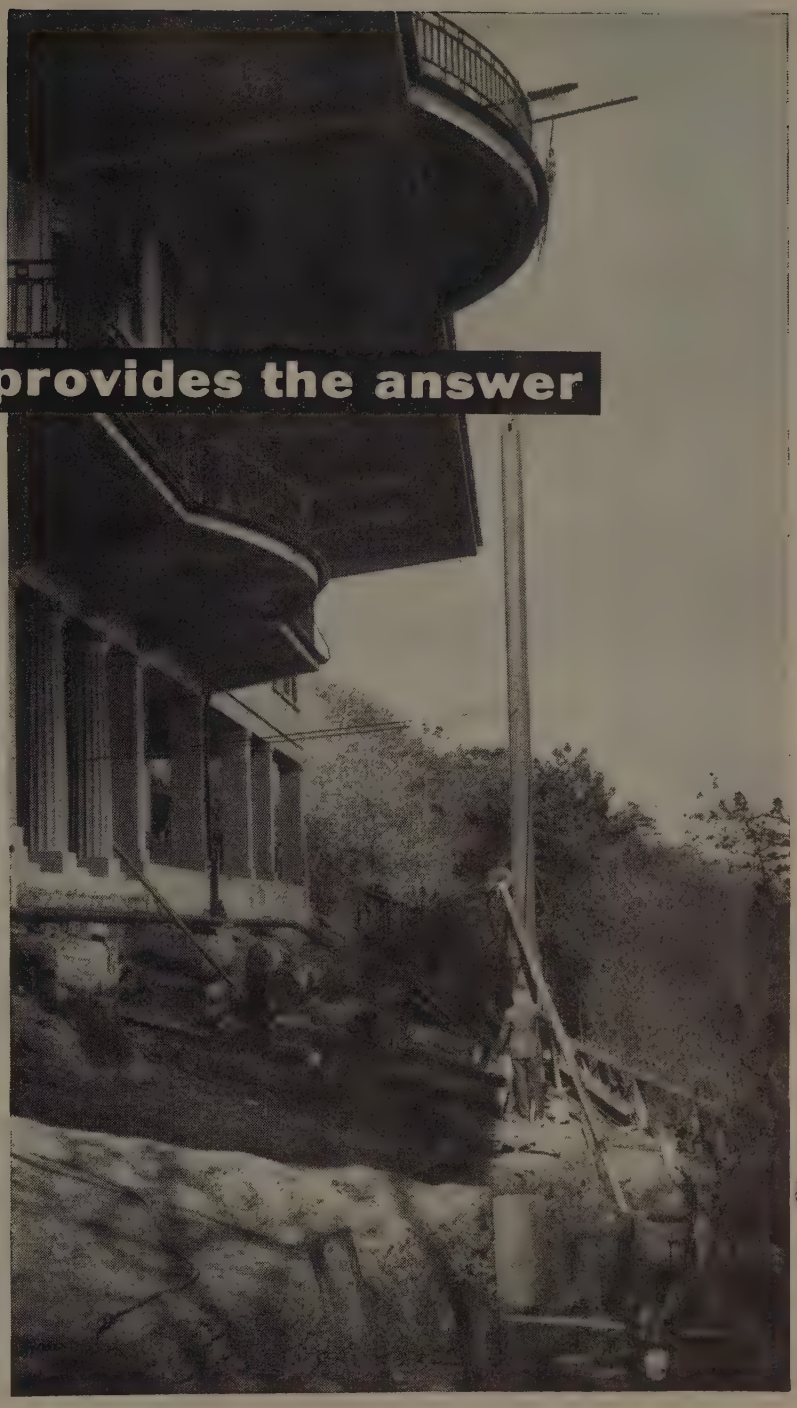

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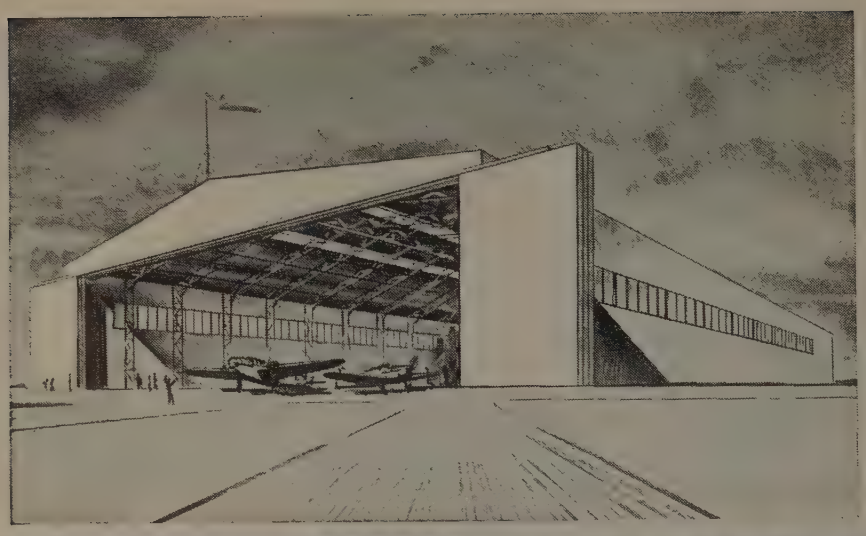

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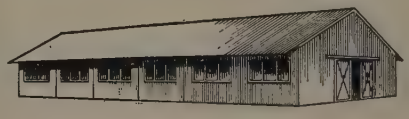

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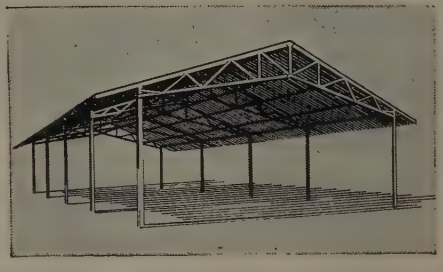

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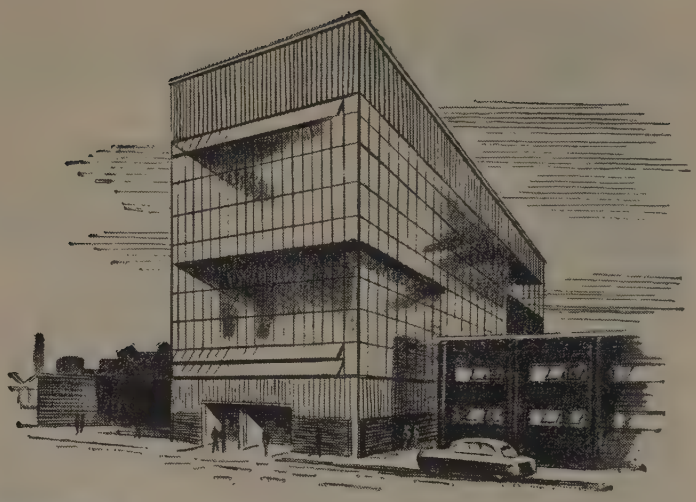

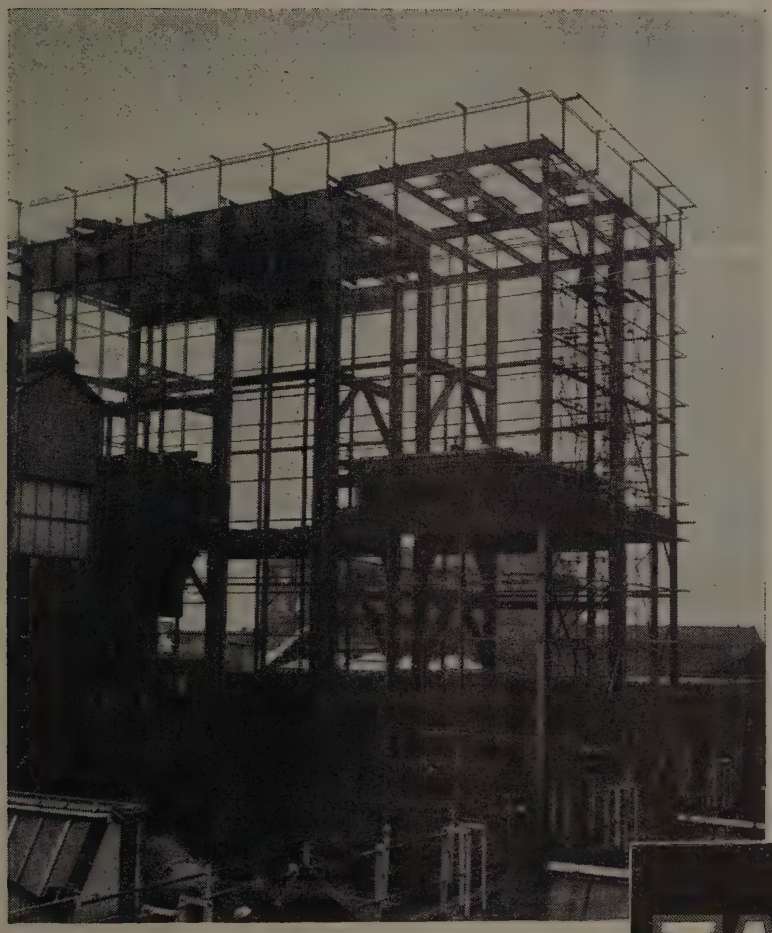

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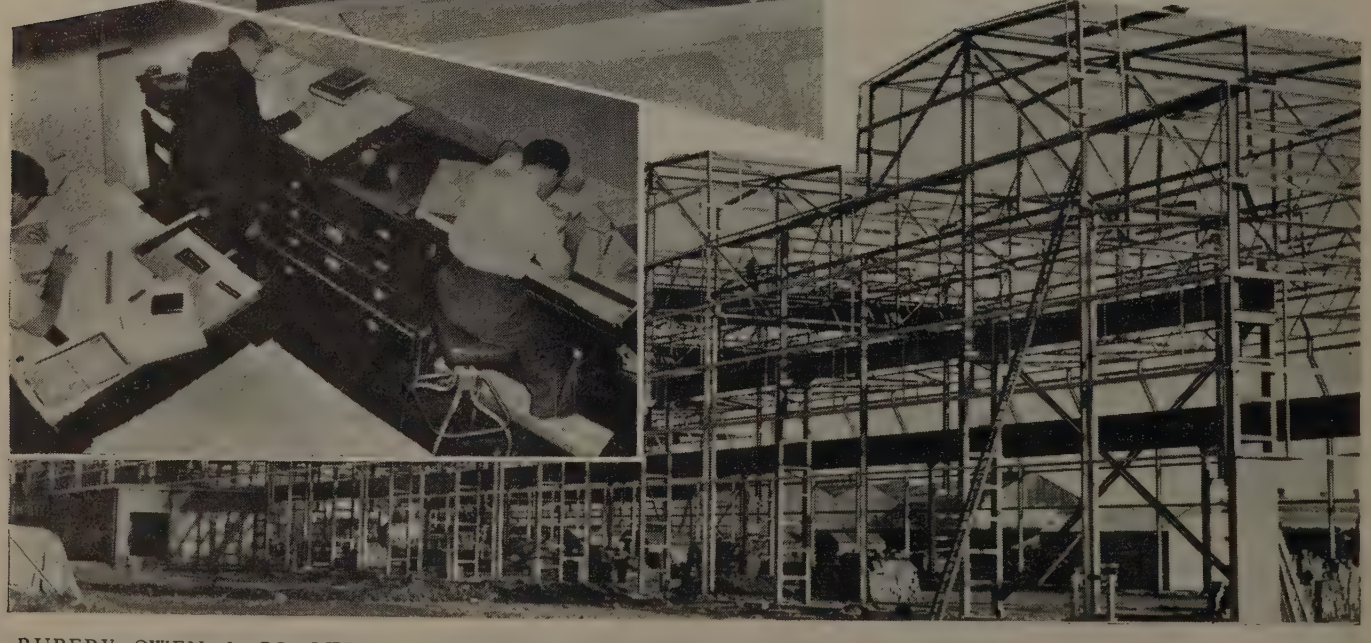

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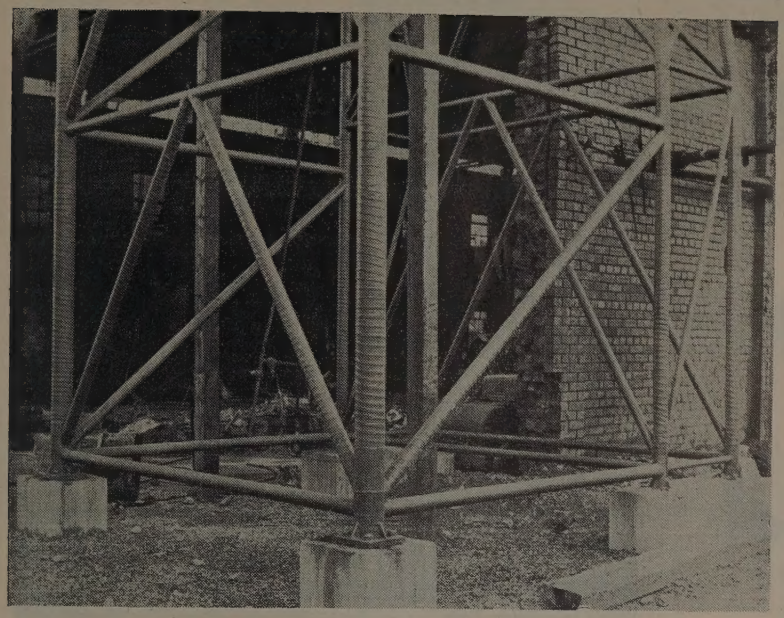

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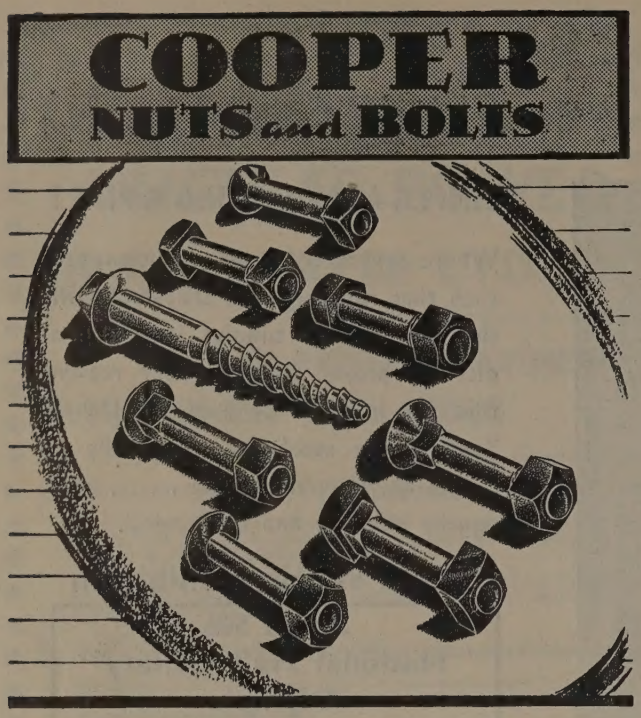

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INDEX TO ADVERTISERS

	Page
Arrol, Sir William & Co. Ltd.	13
Associated Lead Manufacturers Export Co. Ltd.	16
Banister, Walton & Co. Ltd.	5
Bellman Hangars Ltd.	38
Booth, John & Sons (Bolton) Ltd.	3
British Oxygen Gases Ltd.	7
British Reinforced Concrete Eng. Co. Ltd., The	Cover IV
Broom and Wade Ltd.	4
Butterley Co. Ltd., The	10
Cement Marketing Co. Ltd., The	6
Cementation Co. Ltd., The	14
Cooper, George & Sons	44
Dawnays Ltd.	20
Demolition and Construction Co., Ltd.	11
Dickens, Stuart B. Ltd.	9
Dorman Long Ltd.	17
Dow-Mac (Products) Ltd.	30
Dunlop Rubber Co., Ltd.	8
Findlay Alex & Co. Ltd.	36
Fisher & Ludlow Ltd.	15
Franki Compressed Pile Co. Ltd.	18
Ground Exporations Ltd.	14
Hill, Richard Ltd.	Cover II
Johnson, Richard & Nephew Ltd.	12
Jones, T. C. & Co. Ltd.	21
Lafarge Aluminous Cement Co. Ltd.	29
Laing, John & Son Ltd.	32
McCall & Co. Ltd.	22
Mellowes & Co. Ltd.	36
Peirson & Co. Ltd.	2
Pre-Piling Surveys Ltd.	41
Pressure Piling Co. (Parent) Ltd., The	37
Richard Chas. & Sons Ltd.	26
Ruberoid Co. Ltd.	Cover III
Rubery Owen & Co. Ltd.	40
Russell, S. & Sons Ltd.	34
Shot Blasting & Metal Spraying Co. Ltd.	42
Simplex Concrete Piles Ltd.	26
Skinningrove Iron Co. Ltd.	27
South Durham Steel & Iron Co. Ltd.	25
Stent Precast Concrete Ltd.	34
Stramit Boards Ltd.	35
Tentor Bar Co. Ltd.	33
Tileman & Co. Ltd.	24
Tubewrights Ltd.	23
United Coke and Chemicals Co. Ltd.	38
Ward, Thos. W. Ltd.	19
Ward, Thos. W. Ltd.	1
Winn & Coales Ltd.	43
Wood Edward & Co. Ltd.	39
Wright Anderson & Co. Ltd.	28

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